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OF
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URE'S DICTIONARY
OF
ARTS, MANUFACTURES, AND MINES

CONTAINING

A CLEAR EXPOSITION OF THEIR PRINCIPLES AND PRACTICE

BY

ROBERT HUNT, F.R.S.

KEEPER OF MINING RECORDS
FORMERLY PROFESSOR OF PHYSICS, ROYAL SCHOOL OF MINES, ETC.
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assisted by

F. W. RUDLER, F.G.S.

and by numerous Contributors eminent in Science and familiar with Manufactures

Illustrated with upwards of Twenty-one Hundred Engravings on Wood

SEVENTH EDITION

COMPLETELY REVISED AND GREATLY ENLARGED

IN THREE VOLUMES
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A DICTIONARY
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Omissions.

Page 240 *insert* **METEORIC STONES.** See Meteorites.
„ 517 „ **PAVEMENT.** See Bitumen.
„ 628 „ **PREHNITE.** A hydrous silicate of alumina and lime. See Bristow's 'Glossary of Mineralogy.'
„ „ „ **PRESERVED MEATS.** See Putrefaction: *Curing of Provisions.*
„ 682 „ **PYROMORPHITE.** A chlorophosphate of lead. See Lead.

Bread-fruit order. This is the Indian *jaca*, a native of Southern Asia. Its fibres are employed for many purposes by the natives, and the wood is used for furniture. A yellow dye, derived from the inner bark is employed in India for dyeing the robes of the Buddhist priests.

JACKSONITE. A name applied by Whitney to a mineral from Keweenaw Point, Lake Superior. It appears to be nothing more than ordinary prehnite. See Prehnite.

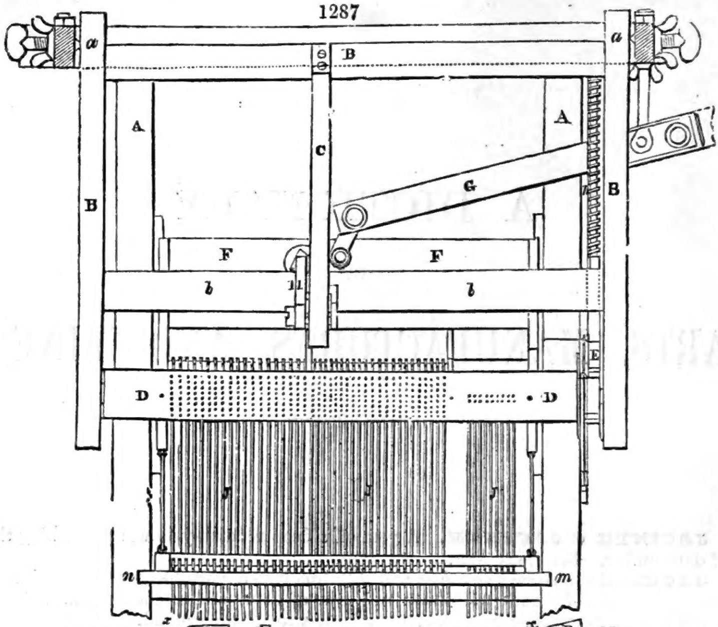
JACQUARD-LOOM. A peculiar and most ingenious mechanism, invented by M. Jacquart of Lyons, to be adapted to a silk and muslin loom for superseding the employment of draw-boys, in weaving figured goods. Independently of the ordinary play of the warp threads for the formation of the ground of such a web, all those threads which should rise simultaneously to produce the figure, have their appropriate healds, which a child formerly raised by means of cords, that grouped them together into a system, in the order, and at the time desired by the weaver. This plan evidently occasioned no little complication in the machine, when the design was richly figured; but the apparatus of Jacquart, which subjects this manœuvre to a regular mechanical operation, and derives its motion from a simple pedal put in motion by the weaver's feet, was generally adopted soon after its invention in 1800. Every common loom is susceptible of receiving this beautiful appendage. It costs in France 200 francs or 8*l.* sterling, and a little more in this country.

Fig. 1287 is a front elevation of this mechanism, supposed to be let down. *Fig.* 1288 is a cross section, shown in its highest position. *Fig.* 1289, the same section as the preceding, but seen in its lower position.

A is the fixed part of the frame, supposed to form a part of the ordinary loom; there are two uprights of wood, with two cross-bars uniting them at their upper ends, and leaving an interval $x\ y$ between them, to place and work the moveable frame B vibrating round two fixed points *a a*, placed laterally opposite each other, in the middle of the space *x y*, *fig.* 1287.

C is a piece of iron with a peculiar curvature, seen in front, *fig.* 1287, and in profile, *figs.* 1288 and 1289. It is fixed on one side upon the upper cross-bar of the frame B, and on the other, to the intermediate cross-bar *b* of the same frame, where it shows an inclined curvilinear space *c*, terminated below by a semicircle.

1287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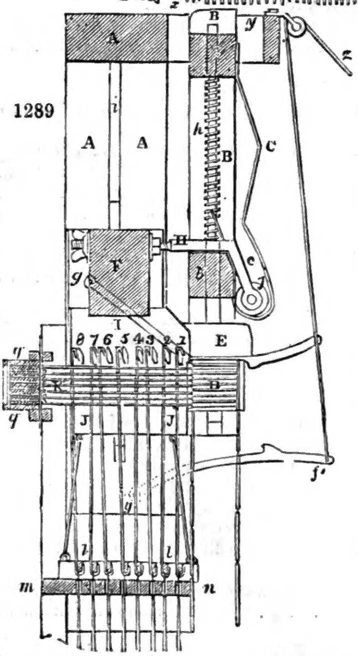
1289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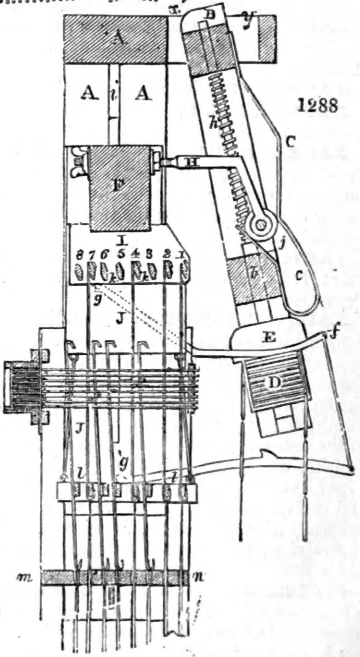
1288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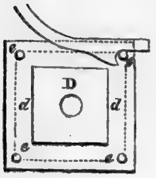
D is a square wooden axis, moveable upon itself round two iron pivots, fixed into its two ends; which axis occupies the bottom of the moveable frame B. The four faces of this square axis are pierced with three round, equal, truly-bored holes arranged in a quincunx. The teeth *a, fig.* 1291, are stuck into each face, and correspond to holes *a, fig.* 1294, made in the cards which constitute the endless chain for the healds; so that in the successive application of the cards to each face of the square axis, the holes pierced in one card may always fall opposite to those pierced in the other.

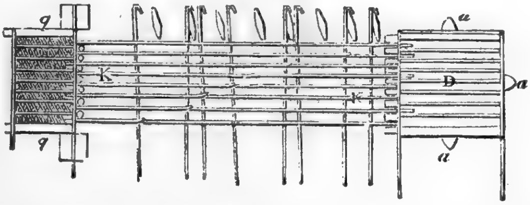
The right-hand end of the square axis, of which a section is shown in double size, *fig.* 1290, carries two square plates of sheet iron *d*, kept parallel to each other and a little apart, by four spindles *e*, passed opposite to the corners. This is a kind of lantern, in whose spindles the hooks of the lever *f f′*, turning round fixed points *g g′* beyond the right-hand upright A, catch hold, either above or below at the pleasure of the weaver, according as he merely pulls or lets go the cord *z*, during the vibratory movement of the frame B.

E is a piece of wood shaped like a T, the stem of which, prolonged upwards, passes freely through the cross-bar *b*, and through the upper cross-bar of the frame B, which serve as guides to it. The head of the T-piece being applied successively against the two spindles *e*, placed above in horizontal position, first by its weight, and then by the spiral spring *h*, acting from above downwards, keeps the square axis in its position, while it permits it to turn upon itself in the two directions. The name *press* is given to the assemblage of all the pieces which compose the moveable frame B B.

1290



1291



F is a cross-bar made to move in a vertical direction by means of the lever G, in the notches or grooves *i*, formed within the fixed uprights A.

H is a piece of bent iron, fixed by one of its ends with a nut and screw, upon the cross-bar F, out of the vertical plane of the piece C. Its other end carries a friction roller J, which, working in the curvilinear space *c* of the piece C, forces this, and consequently the frame B, to recede from the perpendicular, or to return to it according as the cross-bar F is in the top or bottom of its course, as shown in *figs.* 1288 and 1289.

I, cheeks of sheet iron attached on either side to the cross-bar F, which serve as a safe to a kind of claw K, composed here of eight small metallic bars, seen in section, *figs.* 1288 and 1289, and on a greater scale in *fig.* 1291.

J, upright skewers of iron wire, whose tops bent down hookwise naturally place themselves over the little bars K. The bottom of these spindles likewise hooked in the same direction as the upper ones, embraces small wooden bars *l*, whose office is to keep them in their respective places, and to prevent them from twirling round, so that the uppermost hooks may be always directed towards the small metallic bars upon which they impend. To these hooks from below are attached strings, which after having crossed a fixed board *m n*, pierced with corresponding holes for this purpose, proceed next to be attached to the threads of the loops destined to lift the warp threads. K K, horizontal spindles or needles, arranged here in eight several rows, so that each spindle corresponds both horizontally and vertically to each of the holes pierced in the four faces of the square axis D. There are, therefore, as many of these spindles as there are holes in one of the faces of the square.

Fig. 1292 represents one of these horizontal spindles. *n* is an eyelet through which the corresponding vertical skewer passes. *o*, another elongated eyelet, through which a small fixed spindle passes to serve as a guide, but which does not hinder it from moving lengthwise, within the limits of the length of the eyelet. *p*, small spiral springs placed in each hole of the case *q q*, *fig.* 1291. They serve the purpose of bringing back to its primitive position every corresponding needle as soon as it ceases to press upon it.

1292

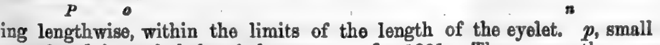
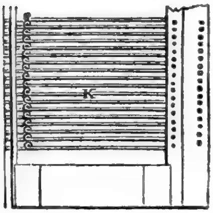
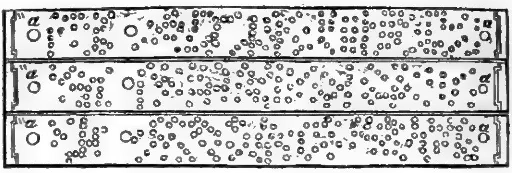


Fig. 1293 represents the plan of the upper row of horizontal needles. *Fig.* 1294 is a fragment of the endless chain, formed with perforated cards, which are made to circulate or travel by the rotation of the shaft D. In this movement, each of the perforated cards, whose position, form, and number are determined by the operation

1293



1294



of tying-up of the warp, comes to be applied in succession against the four faces of the square axis or drum, leaving open the corresponding holes, and covering those upon the face of the axis which have no corresponding holes upon the card.

Now let us suppose that the *press* B is let down into the vertical position shown in *fig.* 1289; then the card applied against the left face of the axis, leaves at rest or untouched the whole of the horizontal spindles (skewers), whose ends correspond to these holes, but pushes back those which are opposite to the unpierced part of the card; thereby the corresponding upright skewers, 3, 5, 6, and 8, for example, pushed out of the perpendicular, unhook themselves from above the bars of the claw, and remain in their place, when this claw comes to be raised by means of the lever G; and the skewers 1, 2, 4, and 7, which have remained hooked on, are raised along with the warp threads attached to them. Then by the passage across of a shot of the colour, as well as a shot of the common weft, and a stroke of the lay after shedding the warp and lowering the press B, an element or point in the pattern is completed.

The following card, brought round by a quarter revolution of the axis, finds all the needles in their first position, and as it is necessarily perforated differently from the preceding card, it will lift another series of warp threads; and thus in succession for all the other cards, which compose a complete system of a figured pattern.

This machine, complicated in appearance, and which requires some pains to be understood, acts however in a very simple manner. Its whole play is dependent upon the movement of the lever G, which the weaver himself causes to rise and fall, by means of a peculiar pedal; so that without the aid of any person, after the piece is properly read in and mounted, he can execute the most complex patterns as easily as he could weave plain goods; only attending to the order of his weft yarns, when these happen to be of different colours.

If some warp yarns should happen to break without the weaver observing them, or should he mistake his coloured shuttle yarns, which would so far disfigure the pattern, he must undo his work. For this purpose, he makes use of the lower hooked lever *f′*, whose purpose is to make the chain of the card go backwards, while working the loom as usual, withdrawing at each stroke the shot both of the ground and of the figure. The weaver is the more subject to make mistakes, as the figured side of the web is downwards, and it is only with the aid of a bit of looking-glass that he takes a peep of his work from time to time. The upper surface exhibits merely loose threads in different points, according as the pattern requires them to lie upon the one side or the other.

Thus it must be evident, that such a number of pasteboards are to be provided and mounted as equal the number of throws of the shuttle between the beginning and end of any figure or design which is to be woven; the piercing of each pasteboard individually will depend upon the arrangement of the lifting rods, and their connection with the warp, which is according to the design and option of the workman; great care must be taken that the holes come exactly opposite to the ends of the needles; for this purpose two large holes are made at the ends of the pasteboards, which fall upon conical points, by which means they are made to register correctly.

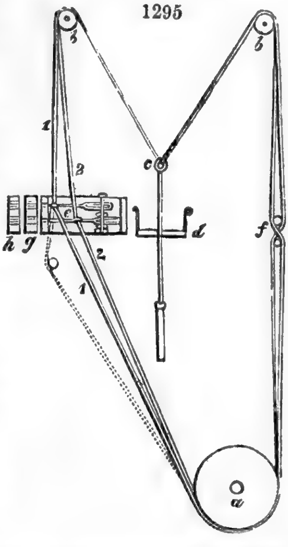
It will be hence seen, that, according to the length of the figure, so must be the number of pasteboards, which may be readily displaced so as to remount and produce the figure in a few minutes, or remove it, or replace it, or preserve the figure for future use. The machine, of course, will be understood to consist of many sets of the lifting rods and needles, shown in the diagram, as will be perceived by observing the disposition of the holes in the pasteboard; those holes, in order that they may be accurately distributed, are to be pierced from a gauge, so that not the slightest variation shall take place.

To form these card-slips, an ingenious apparatus is employed, by which the proper steel punches required for the piercing of each distinct card are placed in their relative situations preparatory to the operation of piercing, and also by its means a card may be punched with any number of holes at one operation. This disposition of the punches is effected by means of rods connected to cords disposed in a frame, in the nature of a false simple, on which the pattern of the work to be performed is first read in.

These improved pierced cards, slips, or pasteboards, apply to a weaving apparatus, which is so arranged that a figure to be wrought can be extended to any distance along the loom, and by that means the loom is rendered capable of producing broad-figured works; having the long lever G placed in such a situation that it affords power to the foot of the weaver, and by this means enables him to draw the heaviest morintures and figured works, without the assistance of a draw-boy.

The machinery for arranging the punches consists of a frame with four upright standards and cross-pieces, which contains a series of endless cords passing under a wooden roller at bottom, and over pulleys at the top. These pulleys are mounted on axles in two frames, placed obliquely over the top of the standard frame, which pulley-frames constitute the table commonly used by weavers.

In order better to explain these endless cords, *fig.* 1295 represents a single endless cord, 1 1, which is here shown in operation, and part of another endless cord, 2 2, shown stationary. There must be as many endless cords in this frame as needles in the weaving-loom. *a* is the wooden cylinder, revolving upon its axis at the lower part of the standards; *b b*, the two pulleys of the pulley-frames above, over which the individual endless cord passes; *c* is a small transverse ring. To each of these rings a weight is suspended by a single thread, for the purpose of giving tension to the endless cord. *d* is a board resembling a common comber-bar, which is supported by the cross-bars of the standard frame, and is pierced with holes, in situation and number corresponding with the perpendicular threads that pass through them; which board keeps the threads distinct from each other.


1295

At *e*, the endless cord passes through the eyes of wires resembling needles, which are contained in a wooden box placed in front of the machine, and shown in this figure in section only. These wires are called the *punch-projectors*; they are guided and supported by horizontal rods and vertical pins, the latter of which pass through loops formed at the hinder part of the respective wires. At *f* are two horizontal rods extending the whole width of the machine, for the purpose of producing the cross in the cords; *g* is a thick brass plate, extending along in front of the machine, and lying close to the box which holds the *punch-projectors*; this plate *g*, shown also in section, is called the *punch-holder*; it contains the same number of apertures as there are punch-projectors, and disposed so as to correspond with each other. In each of these apertures, there is a punch for the purpose of piercing the cards, slips, or pasteboards with holes; *h* is a thick steel plate of the same size as *g*, and shown likewise in section, corresponding also in its number of apertures, and their disposition, with the punch-projectors and the punch-holder. This plate *h*, is called the *punch-receiver*.

The object of this machine is to transfer such of the punches as may be required for piercing any individual card from the punch-holder, *g*, into the punch-receiver, *h*; when they will be properly situated, and ready for piercing the individual card or slip with such holes as have been read in upon the machine, and are required for permitting the warp threads to be withdrawn in the loom, when this card is brought against the ends of the needles. The process of transferring the patterns to the punches will be effected in the following manner:—

The pattern is to be read in, according to the ordinary mode, as in a false simple, upon the endless cords below the rods *f*, and passed under the revolving wooden cylinder *a*, to a sufficient height for a person in front of the machine to reach conveniently. He there takes the upper threads of the pattern, called the *beard*, and draws them forward so as to introduce a stick behind the cords thus advanced, as shown by dots, for the purpose of keeping them separate from the cords which are not intended to be operated upon. All the punch-projectors which are connected with the cords brought forward will be thus made to pass through the corresponding apertures of the punch-holder *g*, and by this means will project the punches out of these apertures, into corresponding apertures of the punch-receiver *h*. The punches will now be properly arranged for piercing the required holes on a card or slip, which is to be effected in the following manner:—

Remove the punch-receivers from the front of the machine; and having placed one of the slips of card or pasteboard between the two folding plates of metal, completely pierced with holes corresponding to the needles of the loom, lay the punch-receiver upon those perforated plates; to which it must be made to fit by mortises and blocks, the cutting parts of the punches being downwards. Upon the back of the punch-receiver is then to be placed a plate or block, studded with perpendicular pins, corresponding to the above described holes, into which the pins will fall. The plates and the blocks thus laid together, are to be placed under a press, by which means the pins of the blocks will be made to pass through the apertures of the punch-receiver; and wherever the punch has been deposited in the receiver by the above process, the said punches will be forced through the slip of pasteboard, and pierced with such holes as are required for producing the figured design in the loom.

Each card being thus pierced, the punch-receiver is returned to its place in front of the machine, and all the punches forced back again into the apertures of the punch-holder as at first. The next sort of cords is now drawn forward by the next *beard*, as above described, which sends out the *punch-projectors* as before, and disposes the punches in the punch-receiver, ready for the operation of piercing the next card. The process being thus repeated, the whole pattern is by a number of operations, transferred to the punches, and afterwards to the cards or slips, as above described.

JACYNTH. See JACINTH—HYACINTH.

JADE. Under the common name of Jade two or three distinct minerals, resembling one another in many of their physical characters, but differing in chemical composition, are popularly confounded. The true jade, or *nephrite*, is an anhydrous silicate of lime and magnesia, related to the non-aluminous varieties of hornblende. *Jadeite* is a mineral closely resembling true nephrite in external characters, but distinguished as a separate species by Damour, whose analyses show that it is essentially a silicate of alumina and soda. A third mineral, originally described by H. B. de Saussure as a jade, was termed *Saussurite* by T. de Saussure: this was the *jade tenace* of Haüy and the early French mineralogists. It is mainly a silicate of alumina and lime, and may be classed with the species termed *zoisite*. The differences in composition between the several minerals comprehended under the general name of jade are shown in the following selected analyses:—

	I.	II.	III.	IV.
Silica	54·68	57·10	59·17	43·59
Lime	16·06	13·48	2·68	19·71
Magnesia	26·01	23·29	1·15	2·98
Soda	...	...	12·93	3·08
Alumina	...	0·72	22·58	27·72
Peroxide of iron	...	...	...	2·61
Protoxide of iron	2·15	3·39	1·56	...
Protoxide of manganese	1·39	...	...	...
Water	0·68	2·50	...	0·35
Total	100·97	100·48	100·07	100·04

I. Nephrite, from China, by Rammelsberg.
II. Nephrite, from New Zealand, by Scheerer.
III. Jadeite, from China, by Damour.
IV. Saussurite, from Lake of Geneva, by T. Sterry Hunt.

It may be useful to give the means of discriminating these minerals by their behaviour before the blowpipe. *Nephrite* is difficult of fusion, does not colour the flame, but when moistened with solution of nitrate of cobalt assumes a rose colour, due to the presence of magnesia; *jadeite* is readily fusible to a transparent glass, and gives with cobalt a blue colour, due to the alumina; *Saussurite* is more fusible than nephrite, but less so than jadeite, it colours the flame blue, and becomes blue with cobalt.

None of the varieties of jade have been found crystallised, but they usually occur in compact tough masses, breaking with a splintery fracture. The specific gravity varies from 2·9 to 3·1, rising to 3·38 in Saussurite. All the jades are hard stones, being nearly as hard as quartz, but it is said that some varieties when first broken, are so soft as to be readily cut with a knife. The colours are various shades of green, occasionally passing into a greenish white tint.

Like most green stones, jade has always been a favourite material for amulets. It formerly possessed special repute for curing diseases of the kidneys, whence the mineralogical name *nephrite* (νεφρός, the kidneys), and the popular name *kidney-stone* (*pierre néphritique*, Fr.; *pietra di hijada*, Sp.; *Nierenstein*, Ger.).

Jade is largely used in China as an ornamental stone under the name of *yu*. Mr. Pumpelly has shown that the jade of the province of Yunnan, known as *fetsui*, is really jadeite. The Chinese appear to have formerly obtained considerable supplies of jade from Eastern Turkestan, where it is found in the chain of the Kuen-lun Mountains. The jade-quarries on the Kara-kash River have been visited and described by Dr. Cayley and by Hermann von Schlagintweit. According to the latter traveller, jade is always known in Khotan under the name of *yashm*.

Jade is found extensively in New Zealand, and is employed by the natives for making *tikis*, or the grotesque ornaments worn on the breast, and for the peculiar instruments of war, called *pattoo-pattoos* or *meres*. The use of jade for these axe-like weapons has led to the popular name of *axe-stone* (*Beilstein*, Ger.). The New Zealand jade is known to the Maories as *punamu* or 'greenstone;' and, according to Von Hochstetter's map it is found along the west coast of the South Island; indeed, this island is called, from the occurrence of jade, *Te Wahi Punamu*, or 'The place of the greenstone.'

Jade also occurs in Siberia, and fine specimens have been brought by M. Alibert, with his graphite, from the Government of Irkutsk.

In prehistoric times, jade and jadeite were used for amulets and ornaments, and specimens have been found among the relics of the old pile-buildings, or *Pfahlbauten*, of the Swiss lakes. It is curious to conjecture whence this material could have been derived; for, with the exception of an erratic block found at Schwemsal in Germany, true jade is not known to occur in western Europe. The so-called jade pebbles of Iona are nothing more than serpentinous marble.—F.W.R.

JADEITE. See Jade.

JAGGERY. Palm-sugar, prepared from *Saguerus saccharifer*

JALAP. The root of the *Exogonium purga*, Bth., a member of the *Convolvulaceæ*, or Bindweed order. It takes its name from Xalapa, a city of Mexico. Its uses as a common purgative are well known.

JAMAICA PEPPER. One of the names given to Allspice.

JAMESONITE. A sulphide of lead and antimony, containing about 40 per cent. of lead and 34 of antimony. It occurs in several mines in the north-east of Cornwall, and in Devonshire, but has not hitherto been available as an ore of lead.

JANAPUM. *Crotalaria juncea*, a vegetable fibre used for ropes. See Fibres.

JAPAN EARTH. *Terra Japonica*. See Gambir.

JAPAN LACQUER. A hard black varnish prepared from the *Stagmaria verniciflua*.

JAPAN PEPPER. A condiment prepared in China and Japan by bruising the capsules of the *Xanthoxylon piperitum*, D.C. From this plant, or from a closely-allied species, Stenhouse obtained two peculiar principles, which he called *Xanthoxylene* and *Xanthoxylin*.

JAPAN SAGO. A starch obtained from the stem of the *Cycas revoluta*.

JAPAN WAX. A vegetable wax obtained from the fruits of *Rhus succedanea*, L., and perhaps other species. It has been imported from Japan for use in candle-making.

JAPANNING is a kind of varnishing or lacquering, practised with excellence by the Japanese, whence the name.

The only difference between varnishing and japanning is that after the application of every coat of colour or varnish, the object so varnished is placed in an oven or stove at as high a temperature as can safely be employed without injuring the articles or causing the varnish to blister or run.

For black japanned works, the ground is first prepared with a coating of black, made by mixing dross ivory black to a proper consistence with dark coloured *anime* varnish, as this gives a blacker surface than could be produced by japan alone. If the surface is required to be polished, five or six coats of japan are necessary to give sufficient body to prevent the japan from being rubbed through in polishing.

Coloured japans are made by mixing with some hard varnishes the required colour, and proceeding as described. See Varnish.

JARGOON, the name given to a variety of Zircon from Ceylon. It is seldom perfectly transparent, and is either colourless or grey, with tinges of green, blue, red, and yellow of various shades, but generally smoky and ill-defined. It occurs in worn angular pieces, or in small detached crystals, rarely exceeding 6 or 8 carats in weight, chiefly in the sand of a river in Ceylon. The surfaces of the crystals are smooth, and possess a lustre more nearly approaching that of the diamond than any other gem. At the present day, though out of fashion and in no request, it is still occasionally sold for inferior diamonds.

Davy says that the light grey varieties of the zircon are sold by the inhabitants of Ceylon as imperfect diamonds, the natives being altogether ignorant of the true nature of the mineral. It is most abundant in the district of Matura, whence it has its common name in Ceylon of *Matura diamond.* The colourless zircon is also cut and sold as a false diamond in the bazaars of India.—H.W.B.

JAROSITE. A hydrous sulphate of peroxide of iron, with an alkaline sulphate. It takes its name from Barranco Jaroso, in the Sierra Almagrera, in Spain.

JASPER (*Jaspe calcédoine*, Fr.; *Jaspis*, Ger.) is a sub-species of quartz, of which there are five varieties:—1. The Egyptian red and brown, forming nodules with ring or tendril-shaped delineations. 2. Porcelain jasper, or clay altered by heat, and differing from true jasper by being fusible on the edges, before the blowpipe. 3. Striped or riband jasper. 4. Common jasper. 5. Agate jasper. The prettiest specimens are cut for seals, and for the inferior kinds of jewellery ornaments. See LAPIDARY.—H.W.B.

JATROPHA MANIHOT. A plant belonging to the *Euphorbiaceæ*, from which the *Cassava meal* is prepared, and from the expressed juice of which are obtained *Cassava starch* and *Tapioca*. See TAPIOCA.

The seeds of *Jatropha purgans* yield jatropha oil, and the nuts of this and some other species of *Jatropha* are known as 'Physic nuts.'

JEAN. A twilled cotton, usually stripped. Satin-jeans are woven so as to present a smooth glossy appearance. It is used for stays, &c.

JELLY, ANIMAL. See GELATINE; GLUE; and ISINGLASS.

JELLY, VEGETABLE. A great many vegetable productions yield upon infusion or decoction gelatinous solutions. These vary very much in character. The jelly of ripe currants and other berries is a compound of mucilage and acid, which loses its power of gelatinising by prolonged ebullition.

JEMMIES. A woollen cloth made in Scotland.

JERKED BEEF. Beef dried in the sun: much of this has been introduced from the South American States, but it has not hitherto been much used, although sold at a very low price.

JERUSALEM ARTICHOKE. The edible tubers of the *Helianthus tuberosus.* The epithet of 'Jerusalem' is a corruption of the Italian *girasol.*

JESSAMINE or **JASMINE.** A well-known family of plants. The *Jasmium fruticans*, a native of the southern parts of France, *J. odoratissimum*, a native of India, and *J. sumbac*, a native of India and Arabia, are used to obtain the essential oil or jasmine. See PERFUMERY.

JET. (*Jaiet*, or *jais*, Fr.) Jet occurs in the upper lias shale in the neighbourhood of Whitby, in Yorkshire, in which locality this beautiful substance has been worked for many hundred years. The jet-miner searches with great care the slaty rocks, and finding the jet spread out, often in extreme thinness between the laminations of the rock, he follows it with great care, and frequently he is rewarded by its thickening out to two or three inches.

The best jet is obtained from a lower bed of the upper lias formations. This bed has an average thickness of about 20 feet, and is known as jet rock. An inferior kind, known as soft jet, is obtained from the upper part of the upper lias, and from the sandstone and shale above it. The production of jet in this country appears to be limited to the coast of Yorkshire, from about nine miles south of Whitby to Boulby, and about the same distance to the north; the estates of Lord Mulgrave being especially productive. There is a curious allusion to this in Drayton's 'Polyolbion':—

> The rocks by Moultgrave, too, my glories forth to set,
> Out of their crannied rocks can give you perfect jet.

Dr. Young, in his 'Geology of the Yorkshire Coast,' writes—'Jet, which occurs here in considerable quantities in the aluminous bed, may be properly classed with fossil wood, as *it appears to be wood in a high state of bitumenisation.* Pieces of wood impregnated with silex are often found completely crusted with a coat of jet about an inch thick. But the most common form in which the jet occurs is in compact masses of from half an inch to 2 inches thick, from 3 to 18 inches broad, and of 10 or 12 feet long. The outer surface is always marked with longitudinal striæ, like the grain of wood, and the transverse fracture, which is conchoidal, and has a resinous lustre, displays the annular growth in compressed elliptical zones.'

It does not appear to us that the 'ligneous origin' of jet is by any means established; indeed, we think the amount of evidence is against it. There is no example, as far as we can learn, of any discovery of true jet having a strictly ligneous structure, or showing anything like the conversion of wood into this coal-like substance. There appears, however, to have been some confusion in the observation of those who have written on the subject. Mr. Simpson, the intelligent curator of the Whitby Museum, who has paid much attention to the subject, says, 'Jet is generally considered to have been wood, and in many cases it undoubtedly has been so; for the woody structure often remains, and it is not unlikely that comminuted vegetable matter may have been changed into jet. But it is evident that vegetable matter is not an essential part of jet, for we frequently find that bone, and the scales of fishes also have been changed into jet. In the Whitby Museum there is a large mass of bone, which has the exterior converted into jet for about a quarter of an inch in thickness. The jetty matter appears to have first entered the pores of the bone, and there to have hardened; and during the mineralising process, the whole bony matter has been gradually displaced, and its place occupied by jet, so as to preserve its original form.' After an attentive examination of this specimen, we are not disposed to agree entirely with Mr. Simpson.

Jet certainly incrusts a mass which has something the structure of a bone, but, without a chemical examination of its constituents, we should hesitate even to say it was bone. Wood without doubt has been found *encrusted* with jet, as fragments of animal matter may also have been. But it is quite inconsistent with our knowledge of physical and chemical changes, to suppose that both animal and vegetable matter would undergo this change. By *process of substitution*, we know that silica will take the place occupied by carbon, or woody matter; as, for example, in the fossil palms of Trinidad, and the silicified forests of Egypt; but we have no example within the entire range of the coal-formations of the world of carbon taking the place of any of the earths.

Jet is found in plates, which are sometimes penetrated by belemnites. Mr. Ripley, of Whitby, has several curious examples,—two plates of jet, in one case enclose water-worn quartz pebbles; and in another jet partially invests an angular fragment of quartz rock. 'This is the more remarkable,' says Mr. Simpson, 'as quartz rock, or, indeed, any other sort of rocky fragment, is rarely found in the upper lias.'

The very fact that we find jet surrounding belemnites, casing adventitious masses of stone, and investing wood, seems to show, that a liquid, or at all events, a plastic condition, must at one time have prevailed. We have existing evidence of this. Dr. Young, in the work already quoted, says:—'In the cavities of nodules containing petrifactions, we sometimes meet with *petroleum*, or *mineral oil*. When first exposed, it is *generally quite fluid* and of a dark green colour; but it soon becomes viscid and black, and at last hardens into a kind of pitch, which generally melts with heat, and when ignited burns with a crackling noise, and emits a strong bituminous smell.' One more sample of evidence in favour of the view that jet has been formed from wood. It is stated (Reed's 'Illustrated Guide to Whitby') that in front of the cliff-work of Hailburne Wyke existed a petrified stump of a tree, in an erect posture, 3 feet high and 15 inches across, having the roots of coaly jet in a bed of shale; whilst the trunk in the sandstone was partly petrified, and partly of decayed sooty wood. Even in this example it would appear, that after all, a coating of jet was all that really existed upon this example of the equisetum, which probably stands where it grew. Mr. Simpson, in a valuable little publication, 'The Fossils of the Yorkshire Lias described from Nature, with a short Outline of the Geology of the Yorkshire Coast,' says:—'From all we know respecting this beautiful mineral, it appears exceedingly probable that it has its origin in a certain bituminous matter, or petroleum, which abundantly impregnates the jet-rock, giving out a strong odour when it is exposed to the air. It is frequently found in a liquid state in the chambers of ammonites and belemnites and other cavities, and, whilst the unsuspicious operator is breaking a lias nodule, it flies out and stains his garment. This petroleum, or mineral oil, also occurs in nodules which contain no organic remains; and I have been informed by an experienced jet-miner that such nodules are often associated with a good seam of jet, and are therefore regarded as an omen of success.'

Jet is supposed to have been worked in this country long before the time of the Danes in England, for the Romans certainly used jet for ornamental purposes. Lionel Charltan, in the 'History of Whitby,' says, that he found the ear-ring of a lady having the form of a heart, with a hole in the upper end for a suspension from the ear; it was found in one of the Roman tumuli, lying close to the jaw-bone. There is no doubt that when the abbey of Whitby was the seat of learning and the resort of pilgrims, jet rosaries and crosses were then common. The manufacture was carried on till the time of

Elizabeth, when it seems to have ceased suddenly, and was not resumed till the year 1800, when Robert Jefferson, a painter, and John Carter made beads and crosses with files and knives:—a neck guard, made in this manner, fetched one guinea. A stranger coming to Whitby saw them working in this rude way, and advised them to try to turn it; they followed his advice and found it answer; several more then joined them, and the trade has been gradually increasing since.

In 1860 the jet-trade of Whitby realised about 45,000*l.*; but since that time it has doubled itself. In 1870 the value amounted to 84,000*l.*; in 1871 to 86,000*l.*; in 1872 to 88,000*l.*; and in 1873 it probably exceeded 90,000*l.*

Two kinds of jet occur at Whitby—the hard and the soft. The hard jet, which alone is now worked, is found in layers of varying extent and thickness; the largest known specimen having measured 6 feet 4 inches in length, about 5 inches in width, and 1½ inch in thickness; it weighed 11½ lbs. Formerly, the hard jet was worked in the cliffs by a dangerous process called 'dessing'; but the cliff-workings are now almost entirely abandoned, and most of the jet is obtained from mines in the Cleveland hills, the most extensive workings being those of Bilsdale, near Broughton. About 20 mines are at present open, giving employment to about 200 miners. Rough hard jet varies in value from 4*s.* to 21*s.* per lb.; but the soft jet realises only 5*s.* 6*d.* to 30*s.* per stone, and it is now rarely worked at Whitby, since Spanish jet can be imported at the same price. The Spanish does not stand wear so well as the Whitby jet, nor does it bear exposure to the weather. The two kinds may be distinguished by scratching them with a knife, the Spanish giving a very irregular scratch, whilst the Whitby gives a fine groove.

In working jet, the first operation is to remove the skin, or outer surface, which is chipped off with an iron chisel; the denuded pieces are then sawn up into sizes adapted for the required articles, and are worked into form by carving and turning; finally, the objects are polished with rouge on a board covered with hide, by which means a fine velvety lustre is obtained. There are at present upwards of 200 workshops in Whitby, the largest being that of Mr. Charles Bryan, which gives employment to about 120 hands. Most of the jet ornaments are sent to London; the inferior ones are mostly purchased for the American market. A trade is also carried on with the Continent and with most of our colonies.

The jet workers complain of the great scarcity of designs in jet. Several designs have been sent them; but the artists not being acquainted with the peculiarities of the material, their designs are not generally applicable, and the manufacturer is much more successful in the imitation of natural objects than any artificial combination.

For recent information on jet, we are indebted to a paper on *Whitby Jet and its Manufacture*, by Mr. J. A. Bower, F.C.S., 'Journal of the Society of Arts,' December 19, 1873.

JETSAM. Goods *cast into the sea* from a ship in stress of weather; *flotsam* being the portion of a ship and cargo which *remains floating upon the waters*; and *lagan*, or *ligan-goods*, being merchandise which is cast overboard, and sunk with a buoy attached, so that they may be possibly discovered.

JEWELLER'S GOLD. Usually an alloy of about 25 per cent. of copper with 75 of gold. See ALLOY.

JEWELLER'S ROUGE. A carefully-prepared peroxide of iron, used for polishing.

JEWELLERY. See BIJOUTRY; GEM; and LAPIDARY.

JEW'S PITCH. A fine variety of asphalt from the Dead Sea. See ASPHALT.

JIGGING, *a mining term.* Separating the ore with a griddle, or wire-bottomed sieve, the heavier substances passing through to the bottom or lower part of the sieve, the lighter substance remaining on the upper part.

JINTA WAN. A substance somewhat resembling caoutchouc, imported from India. See CAOUTCHOUC.

JOHANNITE. Uranium-vitriol, or hydrous sulphate of uranium and copper, found at Joachimstahl in Bohemia, and Johanngeorgenstadt in Saxony.

JUJUBE. The fruit of the *Lizyphus vulgaris* and *L. jujuba*, about the size of, and nearly resembling, a small plum. The French confectioners prepare a lozenge from the juice of the fruit, but nearly all the jujubes sold by our druggists and confectioners are merely dried mucilage, flavoured and sweetened.

JUMPER, *a mining term.* A large borer, steeled at each end like chisel bits. It is worked by the hand.

JUNIPER. A genus of plants belonging to the order *Conifera.* About twenty species are known. This plant is cultivated mostly for its berries, which, when distilled with water, yield a volatile essential oil. The berries are largely employed in the manufacture of Hollands and gin. The French name of the plant is *Genièvre*, and hence our English words 'gin' and 'geneva.'

The *Juniperus Bermudiana*, the Bermuda red cedar, is a large tree with soft and fragrant wood, and is what is used in making pencils, and by cabinet-makers.

The *J. Virginia*, L., is also used as the so-called cedar for lead-pencils.

JUTE consists of the fibres of two plants, called the chonch and isbund (*Corchorus olitorus* and *Corchorus capsularis*), extensively cultivated in Bengal, and forming, in fact, the material of which gunny-bags and gunny-cloth are made. It fetches nearly, though not quite, so high a price as sunn. See SUNN. It comes into competition with flax, tow, and codilla, in the manufacture of stair and other carpets, bagging for cotton and other goods, and such like fabrics, being extensively used for these purposes in Dundee. But it is unsuitable for cordage or other articles into which hemp is manufactured, from its snapping when twisted, and rotting in water.—*M'Culloch.*

The importance of jute as an article of manufacture is shown by the following statement of the *Exports* from India from 1850, when it first began to attract attention in this country, to 1863:—

	Cwts.	Total Value £
1850	391,098	88,989
1851	584,461	196,936
1852	535,027	180,976
1853	340,797	112,017
1854	509,507	214,768
1855	699,566	220,241
1856	882,715	329,076
1857	673,416	274,957
1858	788,820	303,292
1859	317,890	525,099
1860	761,201	290,018
1861	1,092,668	409,372
1862	1,232,279	537,610
1863	1,266,884	750,456

The rapid progress of the jute manufacture in this country is thus shown. The following Tables show the increase since 1869, which is to be accounted for by the low cost of the material, and its possessing a considerable amount of spinning quality.

Imports: nearly all from British India.

Years	Cwts.
1869	2,467,000
1870	2,376,000
1871	3,454,020
1872	4,041,018
1873	4,543,000

The following quantities of yarn and waste of jute were imported in 1871 and 1872:—

	1871		1872	
	lbs.	£	lbs.	£
From Russia	29,000	400	...	...
„ Holland	249,285	4,914	261,844	4,891
„ Belgium	178,787	6,363	28,132	1,347
„ France	2,739,981	50,913	2,285,166	49,631
„ Other countries	...	...	56,929	1,644
Total	3,197,053	62,590	2,632,071	57,513

The President of the Chamber of Commerce, Dundee, at a meeting (1873) stated that great prosperity had attended the Dundee trade during the past year, that the whole machinery had been in operation, and that full employment had been obtained by all. The importation of jute had never been greater than in this year, being some 20,000 tons more than last. It was mentioned as another indication of the prosperity, that the deposits of the working classes engaged in the jute manufacture in the savings-bank during the present year had increased by 36,000*l.* or 37,000*l.*

It is in Scotland especially where goods made from jute represent a large branch of industry. This very cheap raw material is employed there, either pure or mixed, to make ordinary brown cloth, but more especially sacking, packing-cloth, and carpets. The jute yarns used for carpets are of the richest and most varied colours, and are sometimes used in conjunction with cocoa-nut fibre. Even the Brussels and velvet-pile carpets are imitated with success in appearance, but not in durability. Dundee and its surrounding neighbourhood are the principal seats of this fast-increasing manufacture. The number of spindles acting on jute in Dundee is considerably above 50,000. A very beautiful cloth for binding books is made from jute.

The bulk of the raw jute exported is sent to France. About 30,000 cwts. are annually returned in the shape of jute-yarn.

The amount of British-made jute-yarn and manufactures exported was as follows during the last five years:—

	Yarns lbs.	Manufactures yds.
1869	8,041,000	50,127,000
1870	12,669,000	57,920,000
1871	13,710,000	62,310,000
1872	12,715,000	84,452,000
1873	12,275,000	96,539,000

This is exclusive of jute bags and sacks, which are not separately classified in the trade returns.

The following Parliamentary return of the jute *Exports* in 1872 shows the countries to which our manufactures were sent:—

Jute Yarn:	lbs.	£
To Germany	1,684,272	33,521
„ Holland	2,866,952	54,448
„ Belgium	792,540	19,640
„ France	253,900	9,395
„ Spain	4,842,592	96,222
„ Italy	444,680	12,250
„ United States: Atlantic	1,526,619	28,189
„ „ „ Pacific	14,429	278
„ Other countries	289,985	7,296
Total	12,715,969	261,239
Jute Manufactures:	Yards	£
To Russia	771,276	15,343
„ Denmark	1,806,517	29,306
„ Germany	22,552,478	399,494
„ Holland	4,108,478	73,153
„ Portugal and Madeira	920,369	20,319
„ Italy	2,133,050	44,391
„ Austrian Territories	605,162	10,942
„ Turkey Proper	2,324,000	42,286
„ Egypt	822,410	18,757
„ United States: Atlantic	19,829,125	320,461
„ „ „ Pacific	4,292,098	76,860
„ Foreign West Indies	1,209,906	24,831
„ United States of Colombia (New Granada)	646,500	11,415
„ Venezuela	405,200	9,405
„ Peru	2,027,400	35,415
„ Chili	992,200	17,944
„ Brazil	9,061,024	134,638
„ Uruguay	1,387,840	22,620
„ Argentine Republic	3,253,760	52,095
„ British Possessions in South Africa	407,740	11,126
„ Australia	1,342,580	33,278
„ British North America	614,430	18,167
„ Other countries	2,939,370	61,238
Total	84,452,457	1,486,484

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KABOOK. A name for a clay-ironstone in Ceylon.—*Simmonds.*

KAINITE. A hydrous sulphate of potash and magnesia, occurring in the great saline deposits overlying the rock-salt at Stassfurt, in Prussian Saxony. It has become an important commercial source of sulphate of potash.

KAL. *A mining term.* 'Wild iron; a coarse, false kind of iron.'—*Borlase.* In St. Just, in Cornwall, a *callan lode* is a lode containing much iron.

KALEIDOPHON. An instrument devised by Professor Wheatstone. An elastic thin bar is fixed by one of its extremities, and at its free end it carries a silvered or polished ball; a ray of light is reflected from this ball, and when the thin plate is put in vibration, the fine point of light describes various curves, corresponding with the musical notes produced by the vibrations.

KALEIDOSCOPE. A well-known instrument invented by Sir David Brewster. It has been much employed in arts of design. The leading conditions are that the angle at which the reflectors are placed is a submultiple of 360°, that the only positions in which a body can be placed to form perfectly symmetrical images are between the ends of the mirrors, or in contact with the ends, and the eye must be as near as possible to the angular point.

KALI. The Arabs gave this name to an annual plant which grows near the sea-shore, now known under the name of *Salsola soda*, and from whose ashes they extracted a substance, which they called *alkali*, for making soap. The term *Kali* is used by German chemists to denote caustic potash, and *Kalium*, its metallic basis, instead of our *potash* and *potassium.*

KALINITE. Dana's name for native potash-alum. See ALUM.

KAMALA, or **KAMILA DYE.** An Indian yellow dye for silks, obtained from the *Rottlera tinctoria*, Rxb. The red powder which covers the fruit is mixed with alum or with carbonate of soda, and yields an orange dye. Kamala is also employed medicinally in the East.

KAMPTULICON. This article was first made in the year 1843, but, like most new productions, it remained for some time unappreciated. At length it was used by Sir Charles Barry for the corridors of the Houses of Parliament.

At first it was produced in its unstained colour, but subsequently it has been stained of many different colours. It is also impressed with surface-colour designs of varied and appropriate subjects. It is an admirable recipient of colour, which penetrates throughout its substance, and remains permanent. Kamptulicon is composed of gutta-percha, India-rubber, and ground cork.

Other materials have been tried, such as prepared oil and ground cork; but this has not been very successful. In some, sawdust has been substituted for cork.

One of the great advantages of kamptulicon is its property of deadening sound. The Kamptulicon Elastic Floor-Cloth Company, who have extensive works at Bow Common, furnish the following notice of this manufacture:—

The first part of the manufacturing process is the purification of the native caoutchouc or India-rubber. It is first put to soak into large water tanks heated by steam, and when sufficiently softened, is placed before a circular knife of cast steel, revolving at the rate of 3,000 times a minute, and cut into small blocks; and is then taken to a pair of powerful cast-steel rollers, which seize it, and grind it with immense force; and, aided by a jet of water, all the clay and foreign ingredients are expelled and washed away; it is passed several times through this machine, till it is perfectly free from all impurities, when it is taken to a formidable apparatus, called the masticator, which consists of a massive structure of iron, fitted with cylinders, of which every part, being subject to a violent straining, is rendered as strong as possible. The material having been of a loose though tough mass on entering this machine, is gradually crushed and worked down into a body of consistent substance, and has altered to a light brown colour. This process is attended with the evolution of much heat, caused by the immense friction in the working of the material, and any water yet remaining in the mass is actually converted into steam, a succession of explosions constantly being heard in the apparatus from the disengaged air or steam; it is then removed and worked into the proper consistency, by being passed through deeply-indented rollers, which further grind and incorporate it with the different colours, &c., for spreading upon cloth and rolling into sheets for steam packing; this is the most tedious and expensive part of the manufacture, at it goes through several pairs of similar rollers, which require great mechanical power. After being brought to this state, which is varied according to the purpose for which it is required, it is taken to a still larger set of rollers, which consists of four cast-steel cylinders, each of 22 inches diameter, and 62 inches on the face; these rollers are beautifully turned and polished, fitted with steam connections, as well as for hot and cold water, and are estimated to have cost upwards of 1,500*l.*, there being great difficulty in obtaining rollers of so large a size.

The material forms a sheet upon the first roller, and, as it passes over, is pressed into the cloth through the other rolls, and wound off in front of the machine on a roller connected with it, the average speed of the machine being such as to produce 1,500 to 2,000 yards per day. After leaving the machine, the fabric or rubber is subjected to the vulcanising process by being placed with sulphur at temperatures of from 300° to 370° Fahr., which renders the India-rubber highly elastic, and gives it the properties of resisting the influence of grease or acids. The whole of the machinery is worked by a pair of horizontal double-cylinder engines of 66 horse-power, and one engine of 30 horse-power. Space will not permit us to describe the further machinery for making all the various articles in detail.

KANEITE. An arsenide of manganese, probably from Saxony; named after Sir Robert Kane, by whom it was first described.

KANGAROO. A marsupial animal, native of Australia. Its tail makes excellent soup; and its skin, when tanned, becomes a soft and durable leather.

KAOLIN. A name derived from the Chinese, which is sometimes applied to porcelain clay. See CLAY, PORCELAIN.

KARABE', a name of amber, of Arabic origin, in use upon the Continent.

KARN or **CARN.** A Cornish miner's term, frequently, according to Borlase, used to signify the solid rock—more commonly a pile of rocks.

KARSTENITE. The name given by Hausmann to anhydrous sulphate of lime, in compliment to the German mineralogist Karsten. See ANHYDRITE.

KÂT, or **KHAT.** An Arabian drug, obtained from the *Catha edulis* and *C. spinosa.* It is said to be chewed by the Arabs for the sake of its exhilarating effects; whilst a decoction prepared from it is used as tea.

KATTIMUNDOO or **CUTTEMUNDOO.** A caoutchouc-like substance obtained from the *Euphorbia antiquorum* of Roxburgh. It was first exhibited in this country in the Great Exhibition of 1851, being sent by Mr. W. Elliott from Vizagapatam.

It was of a dark brown colour, opaque except in thin pieces, hard and somewhat brittle at common temperatures, but easily softened by heat. Perfectly insoluble in boiling water, but becoming soft, viscid, and remarkably sticky and adhesive like bird-lime, reassuming, as it cools, its original character.

It is said to be used for joining metal, fastening knife-handles, &c.

KAURIE or **KAWRIE RESIN.** See DAMMAR.

KAVA ROOT. The root of the *Piper methysticum*, Forst., used in the South Sea Islands for preparing a disgusting beverage.

KEDGE ANCHOR. A small anchor with an iron stock used for warping.

KEEL. A barge used on the Tyne to carry coal. These barges are constructed to carry 21 tons. The keel 'is worked by means of *one oar* at the gunwale and a *sweep* at the stern. Of late years the build and rig of these vessels have been so greatly improved, that they can now work to windward in as good a style as a sloop.' Dunn, *Winning and Working of Collieries.*

KEELER. A manager of coal barges and colliers in the Durham and Northumberland district.

KEEVE, *a mining term.* A large vat used in dressing ores: also a *brewer's term* for a mash tub.

KEG. A cask containing five gallons.

KEIR. A boiler used in bleaching establishments. See BLEACHING.

KELP (*Varec*, Fr.; *Wareck*, Ger.) is the crude alkaline matter produced by incinerating various species of fuci, or *sea-weed.* They are cut with sickles from the rocks in the summer season, dried and then burned, with much stirring of the pasty ash. Dr. Ure analysed many specimens of kelp, and found the quantity of soluble matter in 100 parts of the best to be from 53 to 62, while the insoluble was from 47 to 38. The soluble consisted of:

Sulphate of soda	8·0	19·0
Soda, as carbonate and sulphuret	8·5	5·5
Muriate of soda and potash	36·5	37·5
	53·0	62·0

The insoluble matter consisted of:

Carbonate of lime	24·0	10·0
Silica	8·0	0·0
Alumina, tinged with iron oxide	9·0	10·0
Sulphate of lime	0·0	9·5
Sulphur and loss	6·0	8·5
	47·0	38·0

The first of these specimens was from Heisker, the second from Rona, both in the Isle of Skye, upon the property of Lord Macdonald. From these, and many other analyses which were made by Dr. Ure, it appears that kelp is a substance of very variable composition, and hence it was very apt to produce anomalous results, when employed as the chief alkaline flux of crown glass, which it was for a very long period. The *Fucus vesiculosus* and *F. nodosus* are reckoned to afford the best kelp by incineration; but all the species yield a better product when they are of two or three years' growth than when cut younger. The *varec* made on the shores of Normandy contains almost no carbonate of soda, but much sulphate of soda and potash, some hyposulphite of potash, chloride of sodium, iodide of potassium, and chloride of potassium; the average composition of the soluble salts being, according to Gay-Lussac, 56 of chloride of sodium, 25 of chloride of potassium, and a little sulphate of potash. The very low price at which soda-ash, the dry crude carbonate from the decomposition of sea salt, is now sold, has superseded the use of kelp for this purpose.

Mr. E. C. C. Stanford has introduced a process for preparing kelp by simply carbonising the weeds. The sea-weeds are collected during the winter, and, when dried and compressed, are distilled in retorts at a comparatively low temperature. See ALGÆ; IODINE; POTASH.

KENTISH RAG. See RAG and RAGSTONE.

KERATIN. An animal principle obtained from hairs, nails, horn, feathers, and other integumentary tissues.

KERMES GRAINS, ALKERMES, are the dried bodies of the female insects of the species *Coccus ilicis*, which lives upon the leaves of the *Quercus ilex* (prickly oak). Kirby and Spence, and also Stephens, state that the *Coccus ilicis* is found on the *Quercus coccifera*. The word *kermes* is Arabic, and signifies 'little worm.' In the middle ages, this dye-stuff was therefore called *vermiculus* in Latin, and *vermeil* and *vermilion* in French. It is curious to consider how the name *vermilion* has been since transferred to red sulphuret of mercury.

Kermes has been known in the East since the days of Moses; it has been employed from time immemorial in India to dye silk; and was used also by the ancient Greek and Roman dyers. Pliny speaks of it under the name of *coccigranum*, and says that there grew upon the oak in Africa, Sicily, &c., a small excrescence like a bud, called *cusculium*; that the Spaniards paid with these grains half of their tribute to the Romans; that those produced in Sicily were the worst; that they served to dye purple; and that those from the neighbourhood of Emerita in Lusitania (Portugal) were the best.

In Germany, during the ninth, twelfth, thirteenth, and fourteenth centuries, the rural serfs were bound to deliver annually to the convents a certain quantity of kermes, the *Coccus Polonicus*, among the other products of husbandry. It was collected from the trees upon St. John's-day, between eleven o'clock and noon, with religious ceremonies, and was therefore called *Johannisblut* (St. John's blood), as also German cochineal. At the above period, a great deal of the German kermes was consumed in Venice, for dyeing the scarlet to which that city gives its name. After the discovery of America, cochineal having been introduced began to supersede kermes for all brilliant red dyes.

The principal varieties of kermes are the *Coccus quercus*, the *Coccus Polonicus*, the *Coccus fragariæ*, and the *Coccus uva ursi*.

The *Coccus quercus* insect lives in the south of Europe upon the kermes oak. The female has no wings, is of the size of of a small pea, of a brownish-red colour, and is covered with a whitish dust. From the middle of May to the middle of June the eggs are collected, and exposed to the vapour of vinegar, to prevent their incubation. A portion of eggs is left upon the tree for the maintenance of the brood. In the department of the Bouches-du-Rhône, one half of the kermes crop is dried.

The kermes of Poland, or *Coccus Polonicus*, is found upon the roots of the *Scleranthus perennis* and the *Scleranthus annuus*, in sandy soils of that country and the Ukraine. This species has the same properties as the preceding; one pound of it, according to Wolfe, being capable of dyeing 10 pounds of wool; but Hermstaedt could not obtain a fine colour, although he employed 5 times as much of it as of cochineal. The Turks, Armenians, and Cossacks dye with kermes their morocco leather, cloth, silk, as well as the manes and tails of their horses.

The kermes called *Coccus fragariæ* is found principally in Siberia, upon the root of the common strawberry.

The *Coccus uva ursi* is twice the size of the Polish kermes, and dyes with alum a fine red. It occurs in Russia.

Kermes is found not only upon the *Lycopodium complanatum* in the Ukraine, but upon a great many other plants.

Good kermes is plump, of a deep red colour, of an agreeable smell, and a rough and pungent taste. Its colouring matter is soluble in water and alcohol: it becomes yellowish or brownish with acids, and violet or crimson with alkalis. Sulphate of iron blackens it. With alum it dyes a blood-red; with copperas, an agate-grey; with sulphate of copper and tartar, an olive-green; with tartar and salt of tin, a lively cinnamon-yellow; with more alum and tartar, a lilac; with sulphate of zinc and tartar, a violet. Scarlet and crimson dyed with kermes were called *grain colours*. The red caps for the Levant are dyed at Orleans with equal parts of kermes and madder, and occasionally with an addition of Brazil-wood. Kermes is but little used in England at present as a dyeing substance.

KERMES, MINERAL. Pure mineral kermes is regarded by Berzelius, Fuchs, and Rose, as an amorphous tersulphuret of antimony. As the preparation has but little use in the arts except as an artist's colour, for its mode of preparation and its chemical constitution, we refer to Watts's 'Dictionary of Chemistry.'

KERMESITE. Red antimony ore, composed of oxygen, 5·29; antimony, 74·45; sulphur, 20·49. It occurs in the form of tufts of cherry-red hair-like crystals, at Bräunsdorf, near Freiberg, in Saxony, and at a few other localities.

KERNEL ROASTING. See COPPER.

KEROSINE. A name given to one of the mineral oils, obtained from the oil-wells and oil-shales of America, and other places.

KERSEY. A coarse stuff woven from long wool, chiefly manufactured in the north of England.

KERSEYMERE. Commonly spelt *cassimere*. A fine fabric woven plain from the finest wools; a manufacture of the west of England principally.

KETCHUP. A name derived from the Japanese *kitjap*. It is prepared from mushrooms, especially from the *Agaricus campestris*, by sprinkling them with salt, letting them drain, and boiling the juice with spices. Walnut-ketchup is made from green walnuts in a similar manner.

KETONES. A class of organic bodies derived from aldehydes by substitution of one atom of hydrogen for one atom of an alcohol-radical. For example, acetone is acetic ketone; that is, it may be regarded as acetic aldehyde in which one atom of hydrogen is replaced by the radical methyl. See Watts's 'Dictionary of Chemistry.'

KHAYA. One of the largest and handsomest trees growing on the western coast of Africa. The wood is of fine quality, and of a reddish colour like mahogany.

KIABOCCA WOOD, called also Amboyna wood. This wood is said to be the excrescence or burr of the *Pterospermum indicum*, or of the *Pterocarpus draco*, from the Moluccas, the Island of Borneo, Amboyna, &c.

KIBBLE, *a mining term.* A bucket usually made of iron, in which the ore is drawn to the surface from the depths of the mine.

KIDDERMINSTER-CARPET. A carpeting so called from the place of its early manufacture. This kind of carpet is now principally made in Scotland. Kidderminster is composed of two webs, each consisting of a separate warped woof. The two are interwoven at intervals to produce the figures. The two webs being passed at intervals through each other, each part being at one time above and the other below, it will be evident, when the webs are of different colours, that the figures will be the same on both sides, only the colours will be reversed. These carpets should be made entirely of wool.

KIESERITE. A hydrous sulphate of magnesia, containing $MgO . SO^3 + HO$ (**$MgSO^4 + H^2O$**). It occurs in large quantities in the upper part of the great saline deposits overlying the rock-salt of Stassfurt, near Magdeberg, in Prussian Saxony. The kieserite is specially characteristic of a zone of the deposits, known as the *kieserite region*, which occurs below the carnallite, and above the polyhalite region. Kieserite forms about 17 per cent. of the salts in that portion of the deposit to which it gives its name. It is separated from the associated salts by solution and crystallisation. Large quantities of sulphate of magnesia prepared from kieserite are now sent into the market by the Stassfurt manufacturers.

The first attempts to economise kieserite were made in 1864, when it was proposed to employ it in the preparation of sulphate of potash. Since that time the applications have greatly increased, and it has now become an important article of commerce.

The largest quantity of the raw material is sent to this country, where it takes the place of the sulphate of magnesia, formerly manufactured from dolomite, or from Grecian magnesite, in cotton printing. Another portion of kieserite is converted into Glauber salts, which, on account of its freedom from iron, are highly prized by gas manufacturers.

Manufacturers of '*blanc fixe*' employ kieserite, instead of sulphuric acid, to precipitate the sulphate of baryta from chloride of barium, and in all similar cases where it is proposed to prepare a difficultly-soluble sulphate, the kieserite can be advantageously used. Kieserite is recommended as a substitute for gypsum in agriculture, as a top-dressing for clover, and is largely employed in England for this purpose. It is proposed to use kieserite in the manufacture of alum. There is a mineral called bauxite, which chiefly consists of the hydrated oxide of aluminium; this is easily dissolved in hydrochloric acid; cheap potash salts and the calculated quantity of kieserite are added; alum crystallises out of the solution, and chloride of magnesium remains in the mother-liquid.

The uses indicated above are wholly inadequate to consume the enormous quantities now obtained from the Stassfurt mines, Millions of pounds of kieserite are annually brought to the surface, and it is becoming a serious question to know what to do with it. If it could be used as a substitute for gypsum in building materials and cements, its cheapness would at once commend it to notice. Experiments looking to this application have been tried.

Two equivalents of kieserite and one equivalent of caustic lime were stirred to a paste in water: the mass hardened, but remained granular and brittle. On calcining it, however, again pulverising and moistening with water, it set to a solid marble-like mass, which could be applied to many useful purposes. It is proposed to employ this material for ornamental decorations in the interior of houses, and in general for the manufacture of cements, and as a substitute for plaster-of-Paris.

Kieserite appears likely to prove a valuable accession to our supply of useful minerals, to be ranked by the side of kainite, a potash mineral also found at Stassfurt, and now largely imported into the United States.

KILBRICKENITE. A variety of Geocronite from Kilbricken, Clare county, Ireland.

KILKENNY COAL. A variety of anthracite.

KILLAS. The name given by the Cornish miners to the *clay slate* of that district. It varies very much in colour and character, being sometimes claywhite, and at other times grey or blue. It is in one district soft; in another compact and hard.

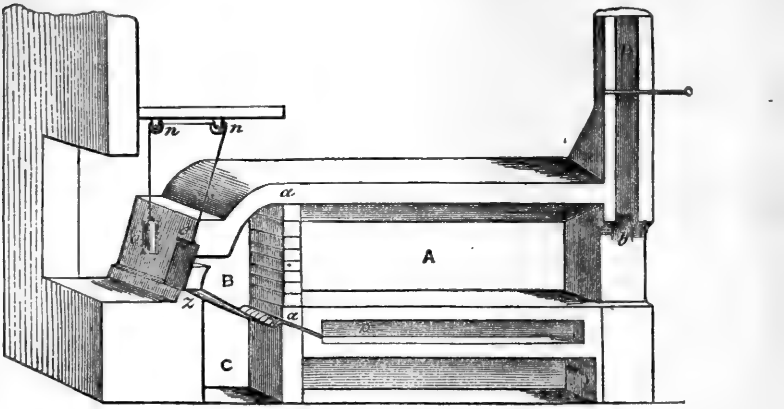
KILN, (*Four*, Fr., *Ofen*, Ger.) is the name given to a certain variety of furnace in which substances can be submitted to the influence of heat. In general, a kiln may be described to be a structure of some considerable size, in which limestones, iron-ores, or the like, can be calcined, bricks and cement stones burnt, pottery baked, or glass annealed.

The ordinary brick-kiln has been already described in the article BRICKS; there are, however, a few modern arrangements which demand some more especial description.

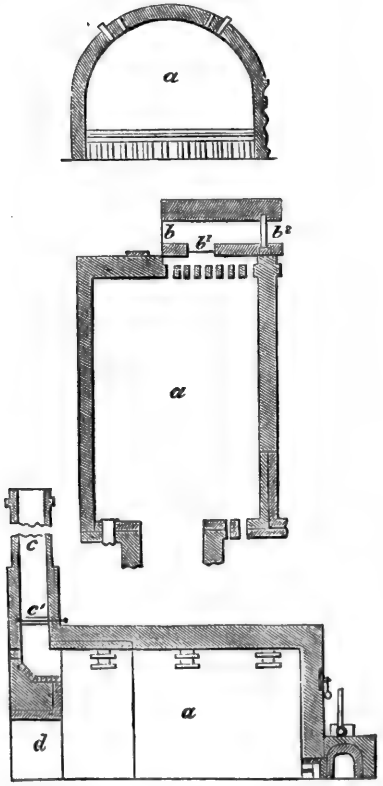
Horizontal Close Kilns.—These are employed very extensively on the Continent. One is represented in *fig.* 1296. Although intended for bricks, it is often advantageously used as an ordinary potter's kiln. A is the firing kiln; B is the fuel-grate; C the ash-pit, and D the chimney. The fire proceeds from the narrow end through the whole length of the kiln to the chimney. Below the flue is the door *b*, which is bricked up during every operation. The perforated wall *a a* separates the fire-hearth from the burning chamber, and diffuses the flame uniformly over the whole front part of the chamber; the position of the fire-grate is found in practice to be exceedingly good, and is recommended. The grate is inclined towards the kiln for the purpose of facilitating the addition of fuel. The curve in the roof conducts the flames, without interruption, into the burning chamber. The fire-door, *e*, can be easily drawn up by means of the weight *o*, and the chains passing over the pulleys *n n*. The flue *p*, and a few others in the side of the kiln, tend to keep the brickwork dry, which is an important point in getting up the heat. The heat in all furnaces thus constructed is greatest in the neighbourhood of the wall *a a*; and to prevent the vitrification of the bricks, a certain quantity of lime is thrown into the front part of the kiln. In such a furnace as this, the firing chamber is 3½ feet high and 10 feet long, and a full charge is 6,000 bricks.

Newcastle Kilns are arched kilns or ovens. These have been improved by Mr. C. G. Johnson, who constructs a flue running along the back of a range of these kilns, and instead of placing the chimney at the end farthest from the fire, he places it near the fire. A communication is formed between the kilns of the flue running along the back of the range. Suitable dampers regulate the heat, which can be drawn through any kiln from back to front by the chimney. *Fig.* 1297 is a front elevation of a portion of a range of kilns thus constructed. *a* is the body of the kiln, where the bricks are stacked

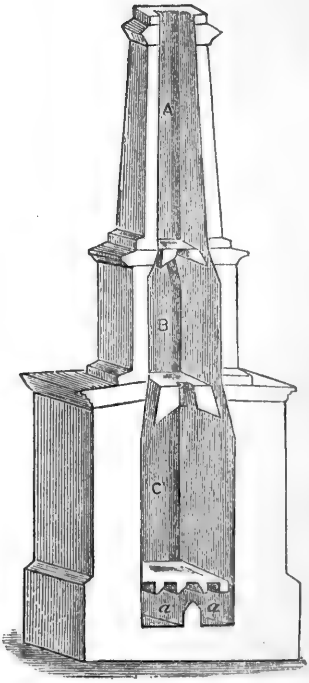
1296



1297



1298



on a plane floor; *b*, a flue that connects any two or more kilns with each other, the communication being regulated by means of dampers b^1 b^2; *c*, chimney with damper *c'*;

d, an archway for setting and drawing the kilns, made up with bricks daubed with clay, so as to be air-tight while the bricks are burning. The system of firing is the same as in the ordinary end firing ovens. The mode of working is simple: No. 1 kiln when fired, is put into communication with No. 2, this kiln having had the opening in front closed up, and the damper in the chimney opened. No. 2 kiln acts as a chimney to No. 1 during the time that the moisture is being driven off from the bricks in it. While this operation is going on, No. 3 kiln can be set, and as soon as the moisture is expelled from the bricks in the first kiln, communication can be closed with No. 2, and that with No. 3 opened. The waste heat will then pass into No. 3. This can be repeated as many times as there are kilns, and the firing up of the kiln with the dried bricks effected.

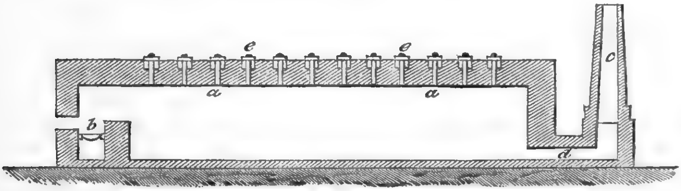
In Hellmann's brick-kiln, at his works near Hanover, the firing-chamber is 8 feet from side to side, 12 feet 8 inches to the top of the arch, and 20 feet 4 inches in length. This space, which is much larger than that in the kiln just described, will contain 24,000 bricks. The mean quantity of coal consumed in firing this kiln is 260 cwts. The kiln is heated from 4 grates, which join in the centre.

The open Dutch kilns are much larger. Heren describes one 51 feet wide, 110 feet long, and 25 feet high, containing 56 layers of bricks, one above the other, consisting of more than 3,000,000 bricks, which are burnt in 36 days by the flames from 10 fires. The *Bihl* kiln (*fig.* 1298) used in Waiblingen is of a similar character. This kiln is heated by two fires; between the fires and the chimney A there are two working chambers, a lower chamber C for burning, and an upper chamber B for drying the bricks. The working chambers and chimney are separated from each other by perforated arches; the lower arch *a a* above the fire being perforated with 25 apertures for the passage of the flames, while between the drying chamber and the chimney there are 13 similar passages. The fuel is placed below the chief chamber C and in front of it, in a prolongation of the fire channels *a a*, in which the grates are set. Several modifications of these kilns have been from time to time introduced, and they have been specially varied to meet the conditions for burning roofing tiles, pipes, &c., but in principle they are essentially the same.

Hoffmann's Straight Kiln.—The following *fig.* (1299) represents in section a kiln on Hoffmann's system as arranged by Chamberlain and Wedekind.

a a is the brick-work of the kiln; *b*, the fire-place at one end, the opposite end opening with a chimney *c*, by a flue *d*; a number of openings *e e*, provided with closely-fitting covers are constructed along the roof of the kilns for the introduction of small fuel. The entire length of the kilns having been filled with bricks, in a fit state for burning, a fire is lighted in the fire-place *b*, and air is allowed to enter freely through the fire-door. When the heat at this end of the kiln is sufficiently high, fuel is introduced through the openings *e e* on the top. The hot air and products of combustion pass along the entire length of the kiln, between the goods stacked in it, gradually heats it, and finally passes off by the flue *d* to the chimney *c*. So soon as that portion of the stacked bricks, into and amongst which the fuel has been supplied, has become sufficiently burnt, the further supply of fuel is stopped, and the supply is then carried on through other openings *e* in advance, so as to mingle the fuel with the adjoining bricks, which by this time will be sufficiently heated to ensure the combustion of such fuel. Those bricks which have been thoroughly burnt are now allowed to cool gradually by the action of the cold air which passes amongst them and takes up the caloric, which is transferred to the succeeding bricks on its way to the chimney. In this manner the process of burning is continued until the extreme end of the kiln has been reached, some of the goods having, in the meantime, been drawn and replaced by fresh ones, so that the kiln will be ready for relighting by the time the last of the goods is withdrawn. These kilns may be provided at intervals with sliding doors, which extend across the kiln, and subdivide it into a number of separate compartments, facility is thus afforded for making use of these compartments as drying

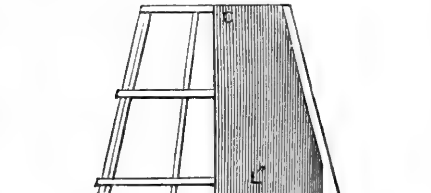
1299



chambers, whilst the other portion of the kiln is burning. The drying may be facilitated by bringing hot air from the cooling portions of the kiln into the drying chamber for the time being, by means of a moveable pipe or flue, which may be adjusted to any of the holes, *e*, in roof. When the bricks are sufficently dry, the doors and flue are removed so as to bring them within the direct range of the hot air and products of combustion from the burning bricks, preparatory to their being fired from above. In this arrangement flues provided with dampers should be employed, leading from each compartment to separate chimneys, or to one common flue leading to a single chimney, and each compartment should have near its upper part a flue for carrying off the steam and vapour, evolved during the process of drying.

Pottery-kilns are sometimes constructed upon this principle, in compartments; the number varying considerably according to the conditions required: these are not usually continuous. The greatest possible heat is required for baking porcelain. The porcelain kiln consists of a round chamber, on the floor of which the porcelain vessels, enclosed in *seggars*, are arranged in columns. The flames fill the whole space, circulating between the columns, and escaping through different apertures in the top of the chamber; from thence they enter a second chamber, and their heat is still sufficient for baking biscuit-ware. *Fig.* 1300 represents the Sèvres porcelain kiln. The kiln is surrounded by four separate fires A A, which first heat the space L, which is intended for completely burning the porcelain; the upper chamber L′ being used for baking the biscuit; while the third space L″ may be used for the same purpose, or for drying the seggars, the flame escaping through the chimney C. The hearths of the porcelain kiln are peculiar; they are constructed without any grate, and built in such a manner that the draught is forced to take a contrary direction to that which it usually takes in other kilns. The space C is filled with red-hot fuel, which is passed in through the aperture *b*, and completely fill the space *f*. The draught in the first instance is downward, in the direction of the arrow, through *b′*, and the spaces between the fuel in *f* and *c*; this creates a long flame, which escapes through *p* into the chamber L. The round aperture *o* is usually closed with a clay stopper; through this opening the fire is stirred; *b*, at the foot of the hearth is used for removing the ashes when necessary, the draught being always regulated by the lid *b′*. The flue is divided by three tongues into three channels *p*, in order that the flame may be dispersed; D and E are the doors for the insertion of the goods. In the arched covering of the space L twenty-five apertures *t t* are left to conduct the flame into the chamber L′. Any single opening would draw all the flame together—the object is to spread it. Half the number of openings are made in the roof of L′ *t′ t′*, for a similar purpose. Small openings are made in the walls of the chamber L, through which the colour of the fire may be watched. The whole of the kiln is bound together with iron bands to prevent its falling to pieces. Such furnaces are usually 20 feet in diameter, they are constructed internally with fire-stone, and surrounded on the outside with bricks.

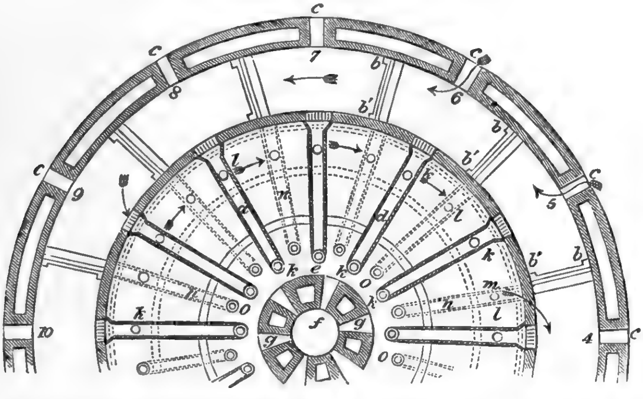
1300



Hoffmann's Continuous Kiln.—*Fig.* 1302 represents a vertical section, and *fig.* 1301 a sectional plan of a continuous kiln, combined with a second or inner chamber, by which dry or warm air may be taken from any of the heated chambers of the kiln to any of the other chambers, for the purpose of drying green bricks or other articles from which it is desired to drive off the moisture. *a*, the brickwork of the kiln, a portion of the annular burning and drying space of which may be shut off or separated from the rest by two moveable diaphragms, *b*, *b′*, to form a drying chamber. The entire kiln is capable of being subdivided into a number of compartments, numbered in *fig.* 1301 from 4 to 10 inclusive, although any other number may be used. Each compartment is provided with a door at *c*, through which the goods are introduced and removed. From the upper part of the several compartments extend a series of flues, *d d*, converging towards, and opening into, an annular smoke-chamber, *e*, which surrounds the chimney, *f*, and communicates therewith by the passages or openings, *g*. The inner ends of these flues inside the smoke chamber are closed or left open by means of conical plugs, *k k*, which, by being elevated, will regulate the amount of opening of the flues. A closed man-hole, *i*, *fig.* 1302, is made in each of these flues for the facility of cleaning. Valves, *k* (*fig.* 1301), connect any one of these flues, when open, with the annular passage, *l*, for dry or warm air, the bottom of the passage communicating, by means of valve *m*, with the flues, *n*, which lead from the lower portion of the compartments of the kiln to the smoke chamber, *e*, before referred to. These flues, *n*, are also provided with conical plugs or dampers, *o*, similar to those which are fitted on to the inner ends of the flues, *d*.

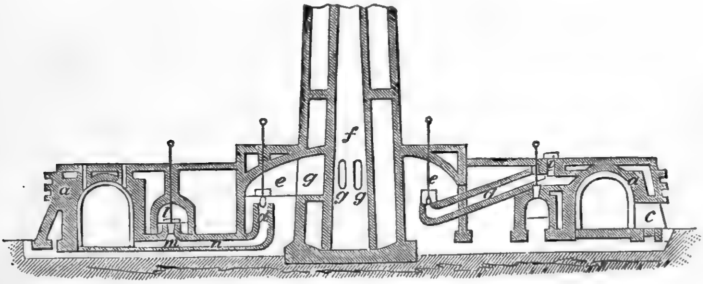
In *fig.* 1301 the chambers 4 and 5 are represented as being shut off from the doors, *b*, *b′*, and are supposed to contain green bricks; the chamber 6 is being filled whilst the goods are being removed from chamber 7; the chambers 8, 9, and 10, all contain burnt goods in the act of cooling; whilst the other chambers are being fired, the hot air therefrom passing through the goods in the chambers 1 and 2 (not shown), and being obstructed by the door, *b*, from entering the drying-chambers 4 and 5 direct, it passes

1301



by the bottom flue, *n*, of the series direct to the smoke-chamber, *e*, and thence to the chimney, the plug or damper, being more or less open for that purpose according to the draught required. The fresh air enters by the doors, *c c*, passes through the heated goods in the chambers 7, 8, and 9, thereby cooling the goods, and at the same time taking up the caloric. A portion of this air so heated passes onwards through the chambers 10, 11, 12, 1, 2, and thence by the flue, *n*, to the chimney, whilst another portion enters one of the flues, *d*, at the mouth thereof, and as the plug or

1302



valve, *h*, on the inner end of this flue is closed, the heated air enters by the open valve, *k*, in the annular chamber or passage, *l*. The warm air then traverses the chamber, *e*, passes through the only open valve, *m*, of the series into the flue, *n*, of the series, the end of which in the smoke chamber is closed by the valve, *o*, and thence to the drying-chamber, 4, and chamber, 3, and finally escaping at *d* by the flue and open plug or valve, *h*, into the smoke chamber, *c*, and chimney, *f*; the whole of the valves, *h*, *o*, *k*, and *m*, are kept closed, except those which are in connection with the flues for the time being; and, so soon as the goods in the drying-chambers 3 and 4 are sufficiently dry for burning, the doors, *b*, are removed, and replaced at *b'*, exposing the bricks in the chamber 3 to the direct action of the heat from the kiln-fires, whilst the chamber 5, just filled with green bricks, forms, with the chamber 4, a drying-chamber. A fresh set of valves or dampers is now opened, and the operations of burning and drying proceed in a continuous manner.

Kilns for special purposes demand especial contrivances; but, usually, they are in principle like one or other of those which have been described. For Malt-Kiln, see MALT.

KIMERIDGE CLAY or **SHALE.** The sands which underlie the Portland stone of Dorsetshire and the south-west of England are based upon a considerable thickness of dark brownish- or bluish-grey clay, to which the term Kimeridge Clay has been given by geologists from the circumstance of its being largely developed and well displayed in the neighbourhood of the village of that name.

Throughout the Isle of Purbeck, but especially in the part of it in question, the clay assumes a very shaly and bituminous character, sometimes passing into more massive beds of brownish shaly coal, possessing a conchoidal fracture.

The Romans, and also the Celts who inhabited the country previously to its invasion by the former nation, appear to have manufactured the harder portions of the shale into cups and other articles, but chiefly into beads, armlets, and bracelets, specimens of which last have been found in the neighbouring barrows, in some cases still encircling the wrists of skeletons.

Circular discs of shale, about the size of a penny piece, have also been dug up in great numbers in this part of the Isle of Purbeck: as many as 600 were, upon one occasion, found closely packed together.

Authorities have been much divided in opinion as to the origin and use of these circular pieces of shale. By some they are supposed to have passed current as money or tokens, whence the name of Kimeridge coal-money, by which they are commonly known, has been applied to them; but the most probable supposition is, that they were the portions of the material fixed to the lathe, and left adhering to it after the armlets or other ornaments of a similar description had been turned from their outer circumferences, and that at some subsequent period these refuse pieces of the turner were worn as amulets or charms by the superstitious.

The shale around Kimeridge abounds in animal and vegetable matter, the former consisting of the shells of oysters, ammonites, &c., together with the bones and teeth of large saurians and fish; while the latter is in so finely divided a state as not to be distinguishable to the eye. Much carbonate of lime and pyrites are also present, especially in those portions in which animal remains are most abundant.

The variation in the external character of the shale is accompanied by a corresponding variation in the relative proportions of mineral and organic matter contained in it; those portions which are the mose fissile and slaty containing a large proportion of mineral matter combined with a relatively small proportion of organic matter; while, on the other hand, in the harder and more massive portions which break with a conchoidal fracture, the organic matter is greatly in excess of the mineral matter, as is shown by the following analyses:—

	Greyish-green delicately fissile shale A		Brown shale with conchoidal fracture B
Amount of volatile matter . . .	19·51	52·8	73·3
„ „ mineral matter . . .	80·49	47·2	26·7
	100·00	100·0	100·0

When heated the shale gives off copious fumes of a disagreeable odour resembling that of petroleum; and when ignited it burns of itself with a dull smoky flame, leaving, when freely exposed to the atmosphere, a reddish ash, which generally retains the form of the original fragment.

The shale has long been used for fuel by the people of the district where it occurs, and the ashes left after combustion have long been known to the farmers on the coast to exercise a beneficial influence upon their crops, especially turnips; but the unpleasant smell given out by it when burning has prevented it from being used, except by the poorer inhabitants.

The composition of this gas, freed from carbonic acid and sulphuretted hydrogen by passing through an ordinary lime purifier, was as follows:—

Olefiant gas and congeners	10·0
Light carburetted hydrogen and hydrogen	79·0
Carbonic oxide	11·0
	100·0

The composition of the coke produced was:—

Carbon	73·4	72·8
Ash	34·3	30·3
	107·7	103·1

The excess above 100 arises from the presence of sulphides in the coal, which during the process of incineration absorb oxygen, and are converted into sulphates.

A ton of shale furnished 11,300 cubic feet of this purified gas, the illuminating power of which, used in the argand burner, consuming 5 cubic feet per hour, equalled that of 20 sperm candles, while the percentage of coke remaining was 36·5.

The liquid and solid products obtained by the distillation of the shale at a low temperature, are an offensively smelling, dark brown oil, suspended in an aqueous liquid, charged with sulphuretted hydrogen, carbonic acid, and ammonia.

This oil, purified and distilled with water, furnished an oily liquid heavier than water; a tar-like residue being left in the retort.

The oily liquid which, when purified, gives out the odour of the finest varieties of coal-gas naphtha, is a mixture of several chemical substances.

When treated with concentrated nitric acid, this oily liquid is divided into two portions, one of which is dissolved by the acid, while the other insoluble portion floats on the surface of the solution in the form of a light colourless oily liquid, resembling in its general character the hydrocarbons of Boghead coal-tar, and of petroleum. The nitric solution which forms the larger proportion of the oily liquid, when mixed with water, furnishes a dense, heavy, yellowish oil, with the odour of nitro-benzol.

Hence it appears that the oily liquid obtained by the distillation of the shale consists chiefly of benzol and its homologues, mixed with small quantities of petroleum hydrocarbons. When sufficiently purified it is applicable for all the purposes for which benzol is employed, for dissolving India-rubber and gutta-percha, for removing stains from fabrics, for preparing varnishes, for making artificial oil of almonds, &c.

On subjecting to distillation without water, and at a rather high temperature, the oily tar-like residue remaining in the retort after the crude volatile oil is obtained by heat from the shale, had been distilled with water, other volatile products are obtained.

The first portion of the oil obtained during the distillation is of an amber colour when first distilled, and much less limpid than the oil produced by distillation with water. It also possesses an offensive sulphurous smell, which, however, is lost on exposure to the air, while the oil assumes a much darker colour. This oil is acted upon by sulphuric, nitric, and hydrochloric acids, by which, especially by the first, a portion of it is resinified.

The remaining portion of the oil, when washed with water and afterwards distilled with steam, furnishes a perfectly colourless oil with the properties of paraffine. This last oil, which forms but a small portion of the original oil, behaves in all respects like the paraffine oil obtained from Boghead cannel coal, and is applicable to the lubrication of machinery, and all the other purposes to which that liquid is applied.

The black, pitch-like, coky residue left in the retort resembles in general character the coke produced from coal in the manufacture of gas.

The ash of the incinerated coke contains nearly the same proportions of silica, alumina, and iron, as Portland cement. The following is an analysis of the ash left by the shale, which contains the larger amount of mineral matter:—

	Ash of Dorsetshire shale	Portland cement
Insoluble residue	29·01	
Peroxide of iron	7·10	5·30
Silica	21·75	22·23
Alumina	10·60	7·75
Lime	20·62	54·11
Carbonic acid	10·92	2·15
	100·00	91·54

Some few years since works were established at Wareham, for the purpose of extracting naphtha, and other products, from the shale by distillation; but the manufacture was abandoned in consequence of the impossibility of destroying the smell given out by the naphtha. We learn (1874) that the works are to be resumed.

The treatment of the shale at Wareham, according to Mr. John C. Mansel, was conducted in the following manner:—

The retorts were charged with about 5 cwts. of shale, prevously broken into pieces about 2 inches square, and the temperature was maintained as nearly uniform as possible. In order to obtain the required uniform temperature the retorts were constructed so as to have backs of lead. The gas formed in the retorts was then condensed by means of a leaden worm, and the product was a crude oil; a large quantity of gas was made during this operation, which was not condensed, but used for ordinary purposes. The crude oil was allowed to stand in long tanks for 48 hours, for the purpose of letting the ammoniacal water (of which there is a large quantity) subside. The oil was then put into a still and rectified once or twice as the case might be. The first product was a light oil, making overproof 75°; the next products were heavy oils, containing paraffine.

The shale, on being taken out of the retorts, was placed in close vessels, and when cool was ground in a mill for manure. In its unmanufactured state the shale was not sufficiently rich in ammonia for this purpose; but at this stage the artificial manure was said to be as valuable as Ichaboe guano, both having been recently analysed for the purpose of comparison. By keeping the temperature low in the retorts, neither the phosphates nor the organic matter were destroyed.

KIMERIDGE COAL. See KIMERIDGE CLAY OR SHALE.

KING'S BLUE. See BLUE PIGMENTS.

KINGSTON'S METAL. An alloy which is known as Kingston's metal is much used for the bearings and packings of machinery. James Pole Kingston patented in 1853 the use of an alloy which he specified as prepared in the following manner:—

An alloy, consisting of copper 9 lbs. and tin 24 lbs., is first melted; then 9 lbs. of mercury are added, and the whole combined. When cooled, it is ready to be used.

KING'S YELLOW. A mixture of arsenious acid and orpiment, used as a pigment.

KING-WOOD is imported from the Brazils, and is sometimes called violet wood. This is one of the most beautiful of the hard woods, and is used in small cabinet work.

KINIC ACID. A peculiar acid extracted by Vauquelin from cinchona.

KINO is an extract obtained most probably from the *Pterocarpus marsupium*, which grows on the Malabar coast. In India kino is used for dyeing cotton a nankeen colour. It is of a reddish-brown colour, has a bitter styptic taste, and consists of tannin and extractive, 75 parts, and a red gum 25 parts. It is used only as an astringent in medicine. Kino is often called a gum, but most improperly so.

KIP. A Malacca weight for tin, of 40 lbs. 11 oz. avoirdupois.—*Simmonds.*

KIPS. The tanners call the skins of young animals kips. The skins of full-grown cattle of small breed are also so called. See LEATHER.

KIRSCHWASSER is an alcoholic liquor obtained by fermenting and distilling bruised cherries, called *Kirschen* in German. The cherry usually employed in Switzerland and Germany is a kind of morello, which on maturation becomes black, and has a kernel very large in proportion to its pulp. When ripe, the fruit, being made to fall by switching the trees, is gathered by children; thrown promiscuously, unripe, ripe, and rotten into tubs; and crushed either by hand, or with a wooden beater. The mashed materials are set to ferment; and, whenever this process is complete, the whole is transferred to a still, and the spirit is run off, by placing the pot over the common fireplace.

The fermented mash is usually mouldy before it is put into the alembic, the capital of which is luted on with a mixture of mud and dung. The liquor has accordingly, for the most part, a rank smell, and is most dangerous to health, not only from its own crude essential oil, but from the prussic acid derived from the distillation of the cherry-stones.

There is a superior kind of *Kirschwasser* made in the Black Forest, prepared with fewer kernels, from choice fruit, properly pressed, fermented, and distilled.

KIRWANITE. A mineral found in basalt on the north-eastern coast of Ireland, consisting of silica, lime, alumina, and protoxide of iron.

KISH. A workman's name for the crystalline scales of graphite, which separate from certain kinds of cast iron on cooling.

KNIFE-CLEANING MACHINES. Mr. Kent's machine for this purpose consists of a box or case, containing a couple of wooden discs, fixed near to each other upon a horizontal iron rod or spindle, which passes through the case, and is caused to rotate by means of a winch-handle. Each disc is, for about three-fourths of the area of its inner face, covered with alternate rows of bristles and strips of leather; and the remaining fourth part is covered with bristles only. The knife-blades to be cleaned are introduced through the openings in the case, between the rubbing surfaces of the discs; and rotatory motion being given to the discs by a winch-handle, the knives are rapidly cleaned and polished.

Mr. Masters constructed knife-cleaning machines upon the same plan as the above; but the rubbing-surface of each disc is formed of strips of buff leather, with only a narrow circle of bristles around the edge of each surface, to clean the shoulders of the knives; small brushes are fixed beneath the holes in the case, through which the blades of the knives are inserted, to prevent the exit of dust from the apparatus.

Mr. Price has also devised a machine for cleaning knives, and another for cleaning forks. The knife-cleaner consists of a horizontal drum, covered with pieces of leather or felt, and fixed within another drum or circular framing, lined with leather or felt. The knives are introduced through openings, in a moveable circular plate, at the front of the outer casing, and enter between the surfaces of the two drums. The plate is fixed upon a horizontal axis, which extends through the case, and is furnished at the back with a handle; by turning which the disc is caused to rotate and carry round the knives between the surfaces of the drums. The fork-cleaner consists of a box, with a long rectangular opening in the side; behind which two brushes are fixed, face to face. Between these brushes the prongs of the forks are introduced, and the handles are secured in a carrier, which is made to advance and recede alternately by means of a throw-crank, and thereby thrust the prongs into and draw them out of contact with the brushes. The carrier consists of two metal plates, the lower one carrying a cushion of vulcanised India-rubber for the fork handles to rest upon, and the upper being lined with leather; they are hinged together at one end, and are connected at the other, when the handles have been placed between them, by a thumb-screw.

KNOLLS. A mining term in Germany for lead ore separated from the smaller parts.

KNOPPERN are excrescences produced by the puncture of an insect upon the flower-cups of several species of oak. They are compressed or flat, irregularly-pointed, generally prickly and hard; brown when ripe. They abound in Styria, Croatia, Sclavonia, and Natolia; those from the latter country being the best. They contain a great deal of tannin, are much employed in Austria for tanning, and in Germany for dyeing fawn, grey, and black. See GALLS.

KOFFO-HEMP. The name in the Moluccas for the Manilla hemp, or rather for the fibres of the wild plantain of those islands, the *Musa textilis*.

KOHL-RABBI. A variety of cabbage (*Brassica oleracea*), in which the stem enlarges into a fleshy excrescence, resembling a turnip.

KOLA NUTS. The bitter seeds of certain species of *Sterculia*, highly esteemed for their medicinal properties by the tribes on the Niger.

KOUMISS is the name of a liquor which the Kalmucks make by fermenting mare's milk, and from which they distil a favourite intoxicating spirit, called *rack* or *racky*.

The milk is kept in bottles made of hide till it becomes sour, is shaken till it casts up its cream, and is then set aside in earthen vessels, in a warm place to ferment, no yeast being required, though sometimes a little old koumiss is added. 21 lbs. of milk put into the still afford 14 oz. of low wines, from which 6 oz. of pretty strong alcohol, of an unpleasant flavour, are obtained by rectification.

KOURIE WOOD. The wood of the New Zealand pine, *Dammara Australis*, one of the most magnificent of the coniferous woods. It is also called *cowdie* and *kaurie* wood. It is much used for the masts of ships.

KRAMERIA. A shrub, which is a native of Peru, yielding the well-known rhatany root, often used as a dentifrice.

KREOSOTE. See CREOSOTE.

KRYOLITE. See CRYOLITE.

KUKUI OIL. An oil expressed from the seeds of the *Aleurites triloba*, or candle-nut tree. It is used as an artist's oil.

KUSS-KUSS. This is the tough fibrous rhizome of an Indian grass. It is woven into a fabric called *tatty* in India; it has an extensive use in the manufacture of awnings, blinds, and sunshades; these are often sprinkled with water during the hot seasons, which, by evaporation, cools the air in the apartment, and at the same time imparts an agreeable odour.

KYANITE. A stone, which is sometimes blue and transparent. It is then employed as a gem; it resembles sapphire. Its chemical composition is, silica, 37·0; alumina, 63·0.

KYANIZING. A process for preserving wood, successfully carried out by the late Mr. Kyan of New York. A solution of corrosive sublimate is forced into the pores of the timber. This chloride of mercury combines with, and coagulates the vegetable albumen, and thus renders the wood impervious to air or moisture.

KYANOL. The old name of aniline. It was applied by Runge to the base from coal-tar.

KYROSITE. A sulphide of copper containing traces of arsenic, from Briccius, near Annaberg, in Saxony.

L

LABARRAQUE'S FLUID. A solution of chloride of soda, occasionally used in bleaching. See Chloride of Lime.

LABDANUM. A resin found on the leaves of the *Cistus Creticus*, in Candia. It is used in perfumery and for pastiles.

LABRADORITE, or **LABRADOR FELSPAR,** is a beautiful mineral, with brilliant changing colours, blue, red, and green, &c. Spec. grav. 2·70 to 2·75. Scratches glass; affords no water by calcination; fusible at the blowpipe into a frothy bead; soluble in muriatic acid; solution affords a copious precipitate with oxalate of ammonia. Cleavages of 93½° and 86½°; one of which is brilliant and pearly. Its constituents are, silica, 55·75; alumina, 26·5; lime, 11; soda, 4; oxide of iron, 1·25; water, 0·5.

Labradorite receives a fine polish, and the beauty of its chatoyant reflections recommends it as an article of ornament.—H.W.B.

In addition to the play of iridescent colours exhibited on the brachydiagonal cleavage-plane of labradorite, the mineral usually presents an aventurine-like appearance due to the enclosure of microscopic scales and crystals (*microliths*). The minute structure of labradorite has recently been studied by Schrauf, of Vienna, and other microscopists. See Felspar.

LABRADOR TEA. An infusion of the leaves of *Ledum palustre* and *L. latifolium*, drunk in parts of North America.

LABURNAM. *Cytisus Laburnam.* (*Arbois commun*, Fr.; *Goldregen*, Ger.) The wood of the laburnam-tree is sometimes used in ornamental cabinet-work and in marquetry. 'In the laburnam there is this peculiarity, namely, that the medullary plates, which are large and very distinct, are white, whereas the fibres are a dark brown—a circumstance which gives an extraordinary appearance to this wood.'—*Aikin.*

LABYRINTH, in *Metallurgy*, means a series of canals distributed from the lead of a stamping-mill; through which canals a stream of water is transmitted for suspending, carrying off, and depositing, at different distances, the ground ores. See Dressing of Ores.

LAC. (*Laque*, Fr.; *Lack, Lackfarben*, Ger.) A resinous substance produced by the puncture of a peculiar female insect, called *Coccus lacca* or *ficus*, upon the branches of several plants; as the *Ficus religiosa* or the pepel tree, the *F. Indica*, the *Rhamnus jujuba*, the *Croton lacciferum* or bihar tree, and the *Butea frondosa*, the Dhak, which grow in Siam, Assam, Pegu, Bengal, and Malabar. The twig becomes thereby incrusted with a reddish mammillated resin, having a crystalline-looking fracture.

The female lac-insect is of the size of a louse; red, round, flat, with 12 abdominal circles, a bifurcated tail, antennæ, and 6 claws, half the length of the body. The male is twice the above size, and has 4 wings; there is one of them to 5,000 females. In November or December the young brood makes its escape from the eggs, lying beneath the dead body of the mother; they crawl about a little way, and fasten themselves to the bark of the shrubs. About this period the branches often swarm to such a degree with this vermin, that they seem covered with a red dust; in this case, they are apt to dry up, by being exhausted of their juices. Many of these insects, however, become the prey of others, or are carried off by the feet of birds, to which they attach themselves, and are transplanted to other trees. They soon produce small nipple-like incrustations upon the twigs, their bodies being apparently glued, by means of a transparent liquor, which goes on increasing to the end of March, so as to form a cellular texture. At this time the animal resembles a small oval bag, without life, of the size of cochineal. At the commencement, a beautiful red liquor only is perceived, afterwards eggs make their appearance; and in October or November, when the red liquor gets exhausted, twenty or thirty young ones bore a hole through the back of their mother, and come forth. The empty cells remain upon the branches. These are composed of the milky juice of the plant, which serves as nourishment to the insects, and which is afterwards transformed or elaborated into the red colouring matter that is found mixed with the resin, but in greater quantity in the bodies of the insects, in their eggs, and still more copiously in the red liquor secreted for feeding the young. After the brood escapes, the cells contain much less colouring matter. On this account, the branches should be broken off before this happens, and dried in the sun. In the East Indies this operation is performed twice in the year; the first time in March, the second in October. The twigs encrusted with the radiated cellular substance constitute the *stick-lac* of commerce. It is of a red colour more or less deep, nearly transparent, and hard, with a brilliant conchoidal fracture. The stick-lac of Siam is the best; it often forms an incrustation fully one quarter of an inch thick all round the twig. The stick-lac of Assam ranks next; and, last, that of Bengal, in which the resinous coat is scanty, thin, and irregular. There are three kinds of lac in commerce: stick-lac, which is the substance in its natural state, seed-lac, and shell-lac. According to the analysis of Dr. John, stick-lac consists of–

An odorous common resin	80·00
A resin insoluble in ether	20·00
Colouring matter analogous to that of cochineal	4·50
Bitter balsamic matter	3·00
Dun yellow extract	0·60
Acid of the stick-lac (laccic acid)	0·75
Fatty matter, like wax	3·00
Skins of the insects, and colouring matter	2·50
Salts	1·25
Earths	0·75
Loss	4·75
	120·00

According to Franke, the constituents of stick-lac, are, resin, 65·7; substance of the lac, 28·3; colouring matter 0·6.

Seed-lac.—When the resinous concretion is taken off the twigs, coarsely pounded, and triturated with water in a mortar, the greater part of the colouring matter is dissolved, and the granular portion which remains being dried in the sun, constitutes *seed-lac.* It contains of course less colouring matter than the stick-lac, and is much less soluble. Mr. Hatchett's analysis of seed-lac was as follows:—

Resin	68
Colouring matter	10
Wax	7
Gluten	5·5
Foreign bodies	6·5
Loss	4
	100

John found in 100 parts of it, resin, 66·7; wax, 1·7; matter of the lac, 16·7; bitter balsamic matter, 2·5; colouring matter, 3·9; dun yellow extract, 0·4; envelopes of insects, 2·1; laccic acid, 0·0; salts of potash and lime, 1·0; earths, 6·6; loss, 4·2.

Shell-lac.—In India the *seed-lac* is put into oblong bags of cotton cloth, which are held over a charcoal fire by a man at each end, as soon as it begins to melt, the bag is twisted so as to strain the liquefied resin through its substance, and, to make it drop upon smooth stems of the banyan-tree (*Musa paradisa*). In this way, the resin spreads into thin plates, and constitutes the substance known in commerce by the name of *shell-lac.*

The Pegu stick-lac, being very dark coloured, furnishes a shell-lac of a corresponding deep hue, and therefore of inferior value. The palest and finest shell-lac is brought from the northern *Circar*. It contains very little colouring matter. A stick-lac of an intermediate kind comes from the Mysore country, which yields a brilliant lac-dye and a good shell-lac.

Shell-lac, by Mr. Hatchett's analysis, consists of resin, 90·5; colouring matter, 0·5; wax, 4·0; gluten, 2·8; loss, 1·8; in 100 parts.

The resin may be obtained pure by treating shell-lac with cold alcohol, and filtering the solution in order to separate a yellow grey pulverulent matter. When the alcohol is again distilled off, a brown, translucent, hard, and brittle resin, of specific gravity 1·139, remains. It melts into a viscid mass with heat, and diffuses an aromatic odour. Anhydrous alcohol dissolves it in all proportions. According to John, it consists of two resins, one of which dissolves readily in alcohol, ether, the volatile and fat oils; while the other is little soluble in cold alcohol, and is insoluble in ether and the volatile oils. Unverdorben, however, has detected no less than four different resins, and some other substances in shell-lac. Shell-lac dissolves with ease in dilute muriatic and acetic acids, but not in concentrated sulphuric acid. The resin of shell-lac has a great tendency to combine with salifiable bases; as with caustic potash, which it deprives of its alkaline taste.

This solution, which is of a dark red colour, dries into a brilliant, transparent reddish brown mass; which may be re-dissolved in both water and alcohol. By passing chlorine in excess through the dark-coloured alkaline solution, the lac-resin is precipitated in a colourless state. When this precipitate is washed and dried, it forms, with alcohol, an excellent pale-yellow varnish, especially with the addition of a little turpentine and mastic.

With the aid of heat, shell-lac dissolves readily in a solution of borax.

The substances which Unverdorben found in shell-lac are the following:—

1. A resin, soluble in alcohol and ether;
2. A resin, soluble in alcohol, insoluble in ether;
3. A resinous body, little soluble in cold alcohol;
4. A crystallisable resin;
5. A resin, soluble in alcohol and ether, but insoluble in petroleum, and uncrystallisable.
6. The unsaponified fat of the *coccus* insect, as well as oleic and margaric acids.
7. Wax.
8. The *laccine* of Dr. John.
9. An extractive colouring matter.

Shell-lac is largely used in the manufacture of sealing-wax and varnishes, and for japanning.

LAC-DYE, *Lac-Lake*, or *Cake-lac*, is the watery infusion of the ground stick-lac, evaporated to dryness, and formed into cakes about two inches square and half an inch thick. Dr. John found it to consist of colouring matter, 50; resin, 25; and solid matter, composed of alumina, plaster, chalk, and sand, 22.

Dr. Macleod, of Madras, states that he prepared a very superior lac-dye from stick-lac, by digesting it in the cold in a slightly alkaline decoction of the dried leaves of the *Menecylon tinctorium* (perhaps the *M. capitellatum*, from which the natives of Malabar and Ceylon obtain a saffron-yellow dye). This solution being used along with a mordant consisting of a saturated solution of tin in muriatic acid, was found to dye woollen cloth of a very brilliant scarlet hue.

The cakes of *lac-dye* imported from India, stamped with peculiar marks to designate their different manufacturers (*the best* DT, the second JMcR, the third CE), are now employed in England for dyeing scarlet cloth, and are found to yield an equally brilliant colour, and one less easily affected by perspiration than that produced by cochineal. When the lac-dye was first introduced, sulphuric acid was the solvent applied to the pulverised cakes, but as muriatic (hydrochloric) acid has been found to answer, it has to a great extent supplanted it. A good *solvent* (No. 1) for this dye-stuff may be prepared by dissolving 3 pounds of tin in 60 pounds of muriatic acid, of specific gravity 1·19. The proper *mordant* for the cloth is made by mixing 27 pounds of muriatic acid of sp. gr. 1·17, with 1½ pound of nitric acid of 1·19; putting this mixture into a salt-glazed stone bottle, and adding to it, in small bits at a time, grain tin, till 4 pounds be dissolved. This solution (No. 2) may be used within twelve hours after it is made, provided it has become cold and clear. For dyeing; three quarters of a pint of the solvent No. 1 is to be poured upon each pound of the pulverised lac-dye, and allowed to digest upon it for six hours. The cloth before being subjected to the dye-bath, must be scoured in the mill with fuller's earth. To dye 100 pounds of pelisse cloth, a tin boiler of 300 gallons capacity should be filled nearly brimful of water, and a fire kindled under it. Whenever the temperature rises to 150° Fahr., a handful of bran, and half a pint of the solution of tin (No. 2) are to be introduced. The froth, which rises as it approaches ebullition, must be skimmed off; and when the liquor boils, 10½ pounds of lac-dye, previously mixed with 7 pints of the solvent No. 1, and 3½ pounds of solution of tin No. 2, must be poured in. An instant afterwards, 10½ pounds of tartar, and 4 pounds of ground sumach, both tied up in a linen bag, are to be suspended in the boiling-bath for five minutes. The fire being now withdrawn, 20 gallons of cold water, with 10½ pints of solution of tin being poured into the bath, the cloth is to be immersed in it, moved about rapidly during ten minutes; the fire is to be then re-kindled, and the cloth winced more slowly through the bath, which must be made to boil as quickly as possible, and maintained at that pitch for an hour. The cloth is to be next washed in the river; and lastly with water only, in the fulling-mill. The above proportions of the ingredients produce a brilliant scarlet tint, with a slightly purple cast. If a more orange hue be wanted, white Florence argal may be used, instead of tartar, and some more sumach. Lac-dye may be substituted for cochineal in the orange-scarlets.

To determine the tinctorial power of lac-dye by comparison with proved samples, a dye-bath is prepared as follows:—5 grains of argal, 20 grains of flannel or white cloth, 5 grains of lac-dye, 5 grains of chloride of tin, 1 quart of water. Heat the water to the boiling point in a tin or china vessel; add thereto the argal, and then the piece of cloth or flannel. Weigh off 5 grains of the lac-dye and pulverise it in a Wedgwood mortar, with the 5 grains by measure of chloride of tin, and pour the whole into the hot liquor containing the cloth, taking care to rinse the mortar with a little of the hot liquor; keep the whole boiling for about half an hour, stirring the cloth or flannel about with a glass rod; then withdraw the cloth, wash and dry it for comparison.

LACCIC ACID crystallises, has a wine-yellow colour, a sour taste, is soluble in water, alcohol, and ether. It was extracted from stick-lac by Dr. John.

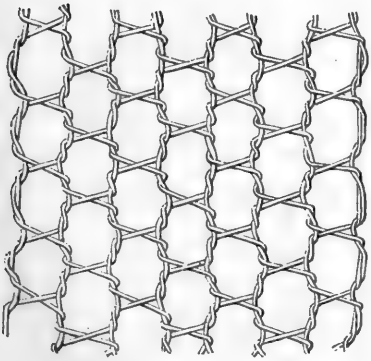
LACCINE is the portion of shell-lac which is insoluble in boiling alcohol. It is brown, brittle, translucid, consisting of agglomerated pellicles, more like a resin than anything else. It is insoluble in ether and oils. It has not been applied to any use.

LACE BARK. The reticulated bark of the *Lagetta lintearia.* This splits into fibres, which resemble lace. Lagetta cloth has been imported into this country under the name of *guana.* The fibres of the lagetta bark possess great strength, and have been used in the West Indies for making ropes, whips, &c.

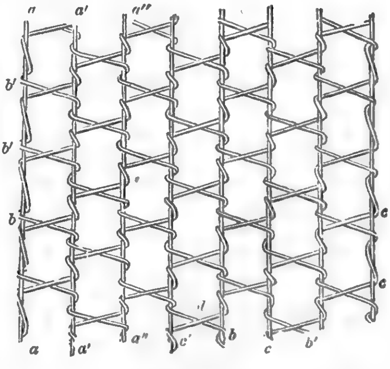
LACE MANUFACTURE. The pillow-made, or bone-lace, which formerly gave occupation to multitudes of women in their own houses, has, in the progress of mechanical invention, been nearly superseded by the bobbin-net lace, manufactured at first by hand-machines, but recently by the power of water or steam. Bobbin-net may be said to surpass every other branch of human industry in the complex ingenuity of its machinery; one of Fisher's spotting frames being as much beyond the most curious chronometer in multiplicity of mechanical device, as that is beyond a common roasting-jack.—*Ure.*

The threads in bobbin-net lace form, by their intertwisting and decussation, regular hexagonal holes or meshes, of which the two opposite sides, the upper and under, are directed along the breadth of the piece, or at right angles to the salvage or border. *Fig.* 1303 shows how, by the crossing and twisting of the threads, the regular six-sided

1303



1304



mesh is produced, and that the texture results from the union of three separate sets of threads, of which one set proceeds downwards in serpentine lines, a second set proceeds from the left to the right, and a third from the right to the left, both in slanting directions. The oblique threads twist themselves round the vertical ones, and also cross each other betwixt them, in a peculiar manner. This may be readily understood by examining the representation. In comparing bobbin-net with common web, the perpendicular threads in the figure, which are parallel to the border, may be regarded as the warp, and the two sets of slanting threads as the weft.

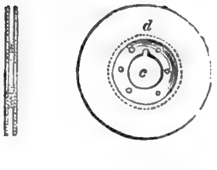
These warp threads are extended up and down, in the original mounting of the piece between a top and bottom horizontal roller or beam, of which one is called the *warp beam*, and the other the *lace beam*, because the warp and finished lace are wound upon them respectively. These straight warp threads receive their contortion from the tension of the weft threads twisted obliquely round them alternately to the right and the left hand. Were the warp threads so tightly drawn that they became inflexible, like fiddle-strings, then the lace would assume the appearance shown in *fig.* 1304; and although this condition does not really exist, it may serve to illustrate the structure of the web. The warp threads stand in the positions $a\ a$, $a'\ a'$, and $a''\ a''$; the one half of the weft proceeds in the direction $b\ b$, $b'\ b'$, and $b''\ b''$; and the second crosses the first by running in the direction $c\ c$, or $c'\ c'$, towards the opposite side of the fabric. If we pursue the path of a weft thread, we find it goes on till it reaches the outermost or last warp thread, which it twists about; not once as with the others, but twice; and then returning towards the other border, proceeds in a reverse direction. It is from this double twist, and by the return of the weft threads, that the selvage is made.

The ordinary material of bobbin-net is two cotton yarns, of from No. 180 to No. 250, twisted into one thread; but sometimes strongly twisted single yarn has been used. The beauty of the fabric depends upon the quality of the material, as well as the regularity and smallness of the meshes. The number of warp threads in a yard in breadth is from 600 to 900; which is equivalent to from 20 to 30 in an inch. The size of the holes cannot be exactly inferred from that circumstance, as it depends partly upon the oblique traction of the threads. The breadth of the pieces of bobbin-net varies from edgings of a quarter of an inch to webs 12 or even 20 quarters, that is, 2 yards wide.

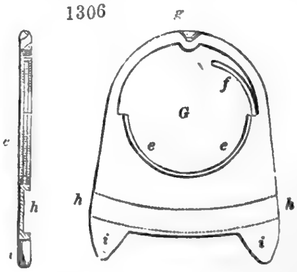
Bobbin-net lace is manufactured by means of very complicated and costly machines, called *frames*. The limits of this Dictionary will admit of an explanation of no more than the general principles of the manufacture. The threads for crossing and twisting round the warp being previously gassed, that is, freed from loose fibres by singeing with gas, are wound round small pulleys, called bobbins, which are, with this view, deeply grooved in their periphery. *Figs.* 1305, 1306, exhibit the bobbin alone, and with its carriage.

In the section of the bobbin *a*, *fig.* 1305, the deep groove is shown in which the thread is wound. The bobbin consists of two thin discs of brass, cut out in a stamp-press, in the middle of each of which there is a hollow space *c*. These discs are riveted together, leaving an interval between their edge all round, in which the thread is coiled. The round hole in the centre, with the little notch at top, serves for spitting them upon a feathered rod, in order to be filled with thread by the rotation of that rod in a species of reel, called the bobbin-filling machine. Each of these bobbins (about double the size of the figure) is inserted into the vacant space G of the carriage, *fig.* 1306. This is a small iron frame (also double the size of the figure), which, at *e e*, embraces the grooved border of the bobbin, and by the pressure of the spring at *f*, prevents it from falling out. This spring serves likewise to apply sufficient friction to the bobbin, so as to prevent it from giving off its thread at *g* by its rotation,

1305

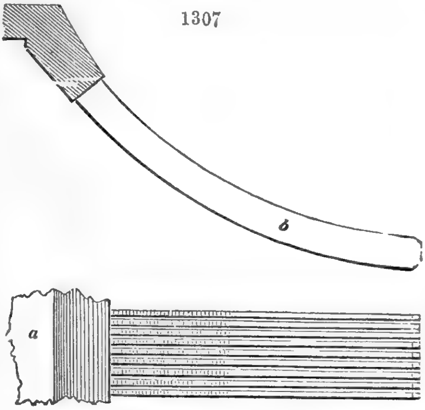


1306



unless a certain small force of traction be employed upon the thread. The curvilinear groove *h h*, sunk in each face or side of the carriage, has the depth shown in the section at *h*. The groove corresponds to the interval between the teeth of the comb, or bars of the bolt, in which each carriage is placed, and has its movement. A portion of that bolt or comb is shown at *a*, *fig.* 1307 in plan, and one bar of a circular bolt machine at *b*, in section. If we suppose two such combs or bolts placed with the ends of the teeth opposite each other, but a little apart, to let the warp threads be stretched, in one vertical plane, between their ends or tips, we shall have an idea of the skeleton of a bobbin-net machine. One of these two combs, in the double bolt machine, has an occasional lateral movement called *shogging*, equal to the interval of one tooth or bolt, by which, after it has received the bobbins, with their carriages, into its teeth, it can shift that interval to the one side, and thereby get into a position to return the bobbins, with their carriages, into the next series of interstices or gates in the other bolt. By this means the whole series of carriages receives successive side steps to the right in one bolt, and to the left in the other, so as to perform a species of counter-march, in the course of which they are made to cross and twist round about the vertical warp threads, and thus to form the meshes of the net.

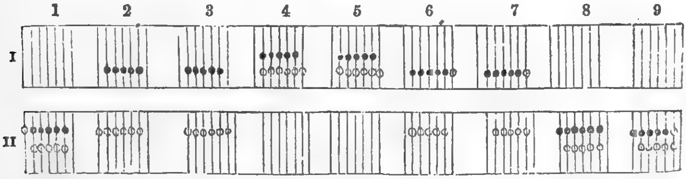
1307



The number of movements required to form a row of meshes in the double tier machine, that is, in a frame with two combs or bars, and two rows of bobbins, is six; that is, the whole of the carriages (with their bobbins) pass from one bar or comb to the other six times, during which passages the different divisions of bobbing and warp threads change their relative positions twelve times.

This interchange or traversing of the carriages with their bobbins, which is the most difficult thing to explain, but at the same time the most essential principle of the lace-machine, may be tolerably well understood by a careful study of *fig.* 1308, in which the simple line | represents the bolts or teeth, the sign ● the black line of carriages, and the sign ɸ the front line of carriages. II is the front comb or bolt bar, and I the back bolt bar. The former remains always fixed or stationary, to receive the carriages as they may be presented to it by the shogging of the latter. There must be always one odd carriage at the end; the rest being in pairs.

1308



No. 1 represents the carriages in the front comb or bar, the odd carriage being at the left end. The black line of carriages is first moved on to the back bar I, the odd carriage as seen in No. 1, having been left behind, their being no carriage opposite to drive it over to the other comb or bar. The carriages then stand as in No. 2. The bar I now shifts to the left, as shown in No. 3; the front carriages then go over into the back bar or comb, as is represented by No. 4. The bar I now shifts to the right, and gives the position No. 5. The front carriages are then driven over to the front bar, and leave the odd carriage on the back bar at the right end, for the same reason as before described, and the carriages stand as shown in No. 6. The bar I next shifts to the left, and the carriages stand as in No. 7 (the odd carriage being thereby on the back bar to the left). The back carriages now come over to the front bar, and stand as in No. 8. The back bar or comb I shifts to the right as seen in No. 9, which completes the traverse. The whole carriages with their bobbins have now changed their position, as will be seen by comparing No. 9 with No. 1. The odd carriage, No. 1, ϕ has advanced one step to the right, and has become one of the front tier; one of the back tier or line ϕ has advanced one step to the left, and has become the odd carriage; and one of the front ones ϕ has gone over to the back line. The bobbins and carriages throughout the whole width of the machine have thus crossed each other's course, and completed the mesh of net.

The carriages with their bobbins are driven a certain way from the one comb to the other, by the pressure of two long bars (one for each) placed above the level of the comb, until they come into such a position that their projecting heels or catches *i i*, *fig.* 1306, are moved off by two other long flat bars below, called the locker plates, and thereby carried completely over the interval between the two combs.

There are six different systems of bobbin-net machines:—1. Heathcoate's patent machine. 2. Brown's traverse warp. 3. Morley's straight bolt. 4. Clarke's pusher principle, single tier. 5. Leaver's machine, single tier. 6. Morley's circular bolt. All the others are mere variations in the construction of some of their parts. It is a remarkable fact, highly honourable to the mechanical judgment of the late Mr. Morley of Derby, that no machines except those upon his circular-bolt principle have been found capable of working successfully by mechanical power.

The circular-bolt machine (comb with curved teeth) was used by Mr. Morley for making narrow breadths or edgings of lace immediately after its first invention; and it has been regularly used by the trade for that purpose ever since, in consequence of the inventor having declined to secure the monopoly of it to himself by patent. At that time the locker bars for driving across the carriages had only one plate or blade. A machine so mounted is now called 'the single-locker circular bolt.' In the year 1824, Mr. Morley added another plate to each of the locker bars, which was a great improvement on the machine for making plain net, but an obstruction to the making of narrow breadths upon them. This machine is now distinguished from the former by the term 'double locker.'

A rack of lace is a certain length of work counted perpendicularly, and contains 242 meshes or holes. Well-made lace has the meshes a little elongated in the direction of the selvage.

Mr. Heathcoate's machine, invented in 1809, was the first successful lace-making machine.

Mr. Morley patented his in 1811; and in the same year Messrs. Marl and Clarke invented the pusher machine, and Messrs. Leaver and Turton, of New Radford, brought forward the lever machine. In 1817, Mr. Heathcoate applied the rotatory movement to the circular-bolt machine, and mounted a manufactory at Tiverton on this plan, where the lace manufacture is still carried on extensively.

LACQUER is a varnish, consisting chiefly of a solution of pale shell-lac in alcohol, tinged with saffron, annotto, or other colouring matters. 'That commonly employed is made by dissolving shell-lac in proof spirit, and colouring with the resinous substance called *dragon's blood*. The lacquer heightens the colour of brass, or renders it more golden in tint. Lacquer may be pale or deep in tint, when it is known as pale or bronze lacquer, or it may be variously coloured. A transparent colourless lacquer is a desideratum for German silver. A substance called bleached shell-lac is sold, and I believe used for very pale lacquer. The lacquer is warmed and brushed over the articles, which have been also previously warmed on stoves. If the temperature is too cold, a dulness of surface is produced, which is not removed by re-heating. The surface of brass is frequently coloured or *bronzed* after 'dipping,' and before lacquering. A dark grey coating is produced by dipping the article in a solution of arsenious acid in hydrochloric acid, by applying a dilute aqueous solution of bichloride of platinum, by applying an aqueous solution of corrosive sublimate mixed with vinegar, or by rubbing plumbago over the surface. By the application of lacquer to the surface of brass, which has received a dark grey coating by any of these processes, a bronze-like tint is produced, due to the light reflected, through the coloured stratum of varnish produced by lacquering, from the bright surface underneath. Precisely the same effect may be obtained by rubbing plumbago over a piece of writing-paper, and then lacquering the surface, as in the case of brass. For common work, the corrosive sublimate method is extensively used; it is said to cause trouble when it comes in contact with softer solder, with which the reduced mercury amalgamates. The platinum process is used for instruments, such as theodolites, levels, &c.; and in these the bronze is much blacker, as pale is employed instead of yellow lacquer. These methods I know are employed, and probably there may be many others. The beautiful colours of brass foils are communicated by variously-coloured lacquers. The coating of resinous matter adheres with remarkable tenacity, and is not detached by bending the foil backwards and forwards repeatedly. The manufacture of these foils is, I believe, quite an art, and formerly there was only one person in Birmingham who knew how to practise it successfully.'—*Percy's Metallurgy.*

LACTIC ACID, $C^{12}H^{12}O^{12}$ ($\mathbf{C^{6}H^{12}O^{6}}$). *Syn.* Nanceic acid. (*Acide lactique*, Fr.; *Milchsäure*, Ger.) Discovered by Scheele in sour milk. Subsequently, M. Braconnot examined the sour liquid which floats above starch during its manufacture, also the acidified decoctions of various vegetables, including beet-root, carrots, peas, &c., and found an acid which he considered to be peculiar, and consequently named the nanceic. The acid formed under all these circumstances turns out to be the same; it is, in fact, lactic acid, which modern researches show to be a constant product of the fermentation of sugar, starch, and bodies of that class. The acidity of sauerkraut is due to the presence of the same substance. Liebig extended and confirmed the experiments made many years ago by Berzelius, on the presence of lactic acid in the juice of flesh, but he denied its existence in urine, as asserted by MM. Cap and Henry, and others.

Preparation.—Lactic acid can be prepared easily in any quantity by the fermentation of sugar. Care must be taken, however, that the process does not go too far, because lactic acid undergoes with facility another decomposition, by which it becomes converted into butyric acid. The following process of M. Bensch for the preparation of lactate of lime can be recommended by the author of this article as yielding at a small trouble and expense a very large quantity of product. In fact, he has prepared with facility upwards of 3 pints of butyric acid from lactate of lime obtained in this manner. Dissolve 6 lbs. of lump-sugar, and ½ oz. of tartaric acid in 2½ gallons of boiling water. Leave for a day or two, and then add 2 oz. of rotten cheese, and a gallon of skimmed milk stirred up with 3 lbs. of well-washed prepared chalk. The temperature should not fall below 86° F. nor rise above 95°. The water lost by evaporation must be made up by adding a little every few days. After a time, varying from 10 days to a month, according to the temperature and other circumstances, the whole becomes a magma of acetate of lime. Two gallons of boiling water must then be added, and ½ oz. of quicklime, and the whole, after being boiled for half an hour, is to be filtered through a linen or flannel bag. The filtered liquid is to be evaporated until it begins to get somewhat syrupy, the fluid in this state being put aside to allow the salt to crystallise. The crystals, after being slightly washed with cold water, are to be recrystallised two or three times. To obtain lactic acid from the lactate of lime, it is necessary, in the first place, to convert the latter salt into that of zinc. For this purpose a crude lactic acid is first obtained thus: to every 2 lbs. 3 oz. of lactate of lime dissolved in twice its weight of boiling water, 7 oz. of oil of vitriol previously diluted with twice its volume of water are to be added. The boiling fluid is to be strained through a linen bag to remove the precipitate of gypsum, and the filtered liquid is to be boiled for 15 minutes with 8¾ oz. of carbonate of zinc. The boiling must not be continued longer, or a subsalt of sparing solubility would be produced. The liquid, which is to be filtered boiling, will deposit on cooling the lactate of zinc in colourless crystals, which are to be washed with a little cold water, and after being drained are to be dried by exposure to the air on frames covered with filtering paper. The mother-liquid will yield a fresh quantity of lactate if it be boiled with the salt remaining on the filter and evaporated.

From the lactate of zinc the acid is to be separated by passing sulphuretted hydrogen through the solution of the salt in eight times its weight of boiling water. The gas is to be expelled by heat, and the fluid on evaporation yields pure syrupy lactic acid.

Lactic acid is a colourless syrupy liquid of a powerful pure acid taste. Its specific gravity is 1·215. It is bibasic.

The most important salts of lactic acid are those of zinc and lime. The former salt is that generally formed in examining animal or vegetable fluids with a view to the isolation of the acid. It is found with two different quantities of water according to the circumstances under which it is prepared, and it is worthy of remark that the amount of water of crystallisation remarkably affects the solubility of the salt in water and alcohol.

All the butyric acid employed for the preparation of butyric ether, or pine-apple essence, is now prepared by the fermentation of lactate of lime.—C.G.W.

LACTOMETER is the name of an instrument for estimating the quality of milk, called also a *Galactometer*. The most convenient form of apparatus would be a series of glass tubes each about 1 inch in diameter, and 12 inches long, graduated through a space of 10 inches, to tenths of an inch, having a stopcock at the bottom, and suspended upright in a frame. The average milk of the cow being poured in to the height of 10 inches, as soon as the cream has all separated at top, the thickness of its body may be measured by the scale; and then the skim-milk may be run off below into a hydrometer glass, in order to determine its density or relative richness in caseous matter, and dilution with water.

LACUSTRINE FORMATION, *a geological term.* Belonging to a lake.

LADANUM. A fragrant gum-resin obtained from several species of *Cistus*, as *C. ladaniferus* and *C. Ledon.* It is used in Turkey as a perfume.

LAGAN GOODS. See JETSAM.

LAKES. Under this general title are included all those pigments which are prepared by combining vegetable or animal colouring matter with earths or metallic oxides. The general method of preparation is to make an infusion of the substance, and to add thereto a solution of common alum; or sometimes, when it has been necessary to extract the colouring matter by the agency of an acid, a solution of alum saturated with potash. At first, a slight precipitate falls, consisting of alumina and the colouring matter; but if some alkali is added, the precipitate is increased. Some colouring matters are brightened by alkalis; then the decoction of the dye-stuff is made in an alkaline liquor, and being filtered, a solution of alum is poured into it. Where the affinity of the colouring matter for the subsulphate of alumina is great, alumina recently precipitated is agitated with the decoction of the colouring body. The manufacture of lakes depends on the remarkable property possessed by alumina, of combining with, and separating the organic colouring matters from their solutions.

Red Lakes.—The finest of these is CARMINE, which, as carminated lakes, called lake of Florence, Paris, or Vienna, is usually prepared by taking the liquor decanted from the carmine, and adding freshly-precipitated alumina to it. The mixture is warmed a little, briskly agitated, and allowed to settle. Sometimes alum is dissolved in the decoction of cochineal, and then the alumina precipitated by potash; but the colour is not good when lakes are thus prepared, and to improve it the dyer's solution of tin is often added. A red lake may be prepared from kermes in a similar manner.

Brazil-wood yields a red lake. The wood is boiled in a proper quantity of water for 15 minutes, and then alum and solution of tin being added, the liquor is to be filtered, and solution of potash poured in as long as it occasions a precipitate. This is separated by a filter, the powder well washed, and being mixed with a little gum-water, made into cakes. Sometimes the Brazil-wood is boiled with vinegar, instead of water. An excess of potash produces a lake of a violet colour, and cream of tartar gives it a brownish hue.

Madder is much used in the preparation of lakes.

The following process is recommended:—

Diffuse 2 lbs. of ground madder in 4 quarts of water, and after a maceration of 10 minutes strain and squeeze the grounds in a press. Repeat this maceration, &c., twice upon the same portion of madder. It will now have a fine rose colour. It must then be mixed with 5 or 6 lbs. of water and ½ lb. of bruised alum, and heated upon a water-bath for 3 or 4 hours, with the addition of water, as it evaporates; after which the whole must be thrown on a filter-cloth. The liquor which passes through is then to be filtered through paper, and precipitated by carbonate of potash. If potash be added in three successive doses, three different lakes will be obtained of diminishing beauty. The precipitates must be washed until the water comes off colourless, then with gum-water made into cakes.

Yellow Lakes are made with decoctions of Persian or French berries, to which some potash or soda is added; into the mixture a solution of alum is to be poured so long as any precipitate falls. Quercitron will yield a yellow lake, provided the decoction is purified by either butter-milk or glue. Annotto lake is formed by dissolving this substance in a weak alkaline lye, and adding a solution of alum to the solution.

Lakes of other colours can be prepared in a similar manner; but true lakes of other colours are not usually manufactured.

LAMINABLE is said of a metal which may be extended by passing between steel or hardened (chilled) cast-iron rollers.

In the manufacture of rail and bar iron, laminated iron is rolled together at a welding heat, until the required bar or rail is formed (see RAILS). This is, even under the best possible circumstances, a defective manufacture. The union of the bars is never absolutely complete, and the result of the long-continued action of trains of carriages upon all rails is the development of the laminated plates, which frequently *peel* off, layer after layer, to the destruction of the rail, and to the great danger of the traveller. Railway iron should be rolled into form from perfectly homogeneous masses of metal. This lamination of iron rails has been laid hold of by those who advocate the hypothesis that the slate rocks owe their lamination to mechanical pressure, whereas it is evidently the result of an imperfect manufacture. See ROLLING MILLS.

LAMING'S MIXTURE. A mixture of porous hydrous peroxide of iron with sawdust, used for absorbing sulphuretted hydrogen in the purification of coal-gas. The sulphur accumulated in this mixture may be recovered by calcination, or by means of steam.

LAMIUM ALBUM, or the dead nettle, is said by Leucus to afford from its leaves a greenish-yellow dye. The *L. purpureum* dyes a reddish-grey with salt of tin, and a greenish tint with iron-liquor.

LAMP-BLACK. Every person knows that when the combustion of oil in a lamp is imperfect it pours forth a dense volume of black soot. According to the quantity of carbon contained in the material employed, so is the illuminating power of the flame produced by combustion. If, therefore, we have a very brilliant flame, and we subject it to any conditions which shall impede the progress of the combination of the carbon with the oxygen of the air, the result is at once the formation of solid carbon, or lamp-black. This is exhibited in a remarkable and often an annoying manner by the camphine lamp. If oil of turpentine, resin, pitch-oil, or fat-oil, be burnt in lamps under a hood, with either a rapid draught or an insufficient supply of air, the lamp-black collects on the hood, and is occasionally removed. Sometimes a metallic roller, generally of tin, is made to revolve in the flame, and rub against a brush. By the cooling influence of the metal, the heat of the flame is diminished, the combustion retarded, and the carbon deposited, and in the revolution of the cylinder swept off. Camphor burning forms a very beautiful black, which is sometimes used as a pigment.

The common varieties of lamp-black are made from all sorts of refuse resinous matters, and from the rejected fragments of pine-trees, &c. In Germany, a long flue is constructed in connection with the furnace in which the resinous substances are burnt, and this flue communicates with a hood, composed of a loose woollen cloth, held up by a rope passing over a pulley. Upon this the soot collects, and is from time to time shaken down. In the best-conducted manufactories about 3 cwts. of lamp-black is collected in each hood in about twelve hours. In England, lamp-black is sometimes prepared from the refuse coking coal, or it is obtained in connection with coke-ovens. The lamp-black, however, obtained from the combustion of coal or woody matter is never pure. See Animal Black; Bone Black; Ivory Black.

LAMP, DAVY. See Safety Lamp.

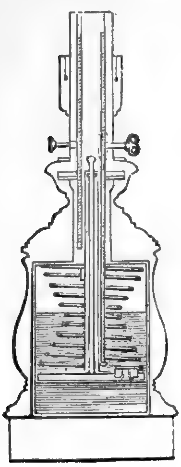
LAMPS. Under Illumination, will be found some notices of several kinds of lamps, with especial reference to the quantity of light produced by them.

Lamps are very varied in form, and equally varied in the principles involved. A brief description, however, of a few of the modern varieties is necessary.

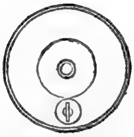
The Moderator Lamp.—The spiral spring has been introduced into the moderator lamps, for the purpose of forcing the oil up the wick of the lamp. This will be understood by the following description and drawings:—The distinguishing character of the moderator lamp is the direct transmission of the power, in the reservoir of oil, to the resistance offered by the weight of the column of oil, as it rises to the cotton;—and secondly, the introduction of a rectangular regulator, which equilibrates constantly by the resistance of the oil and the force applied to raise it. In the reservoir (*fig.* 1309), is a spiral spring which presses on the disc or piston, *fig.* 1310, which is furnished with a valve opening downwards. This spring is attached to a tooth-rack, worked by a pinion wheel, by means of which it is wound up. The mechanical force of the spring is equal to from 15 to 20 pounds; and as this force is exerted upon the disc, floating on the oil, this is forced up through the tube, and it overflows to the argand burner, thoroughly saturating the cotton, and supplying a constant stream of oil. This oil falls back into the reservoir, and is, of course, above the disc. When the spring has run down, it is again wound up; and then the valve opening downward allows the oil to flow back beneath the disc, to be again forced up through the tube. As the pressure employed is so great, the oil would, but for the 'moderator,' flow over with too much rapidity. This *moderator*, or regulator, is a tapering rod of iron-wire, which is placed in the ascending tube; and, as the pressure increases, it is forced more into it, and checks the flow of oil; whereas as it diminishes it falls, and being tapering, allows more oil to rise. Several ingenious adjustments are introduced into these lamps, as manufactured by the Messrs. Tylor of Warwick Lane, with which we need not at present deal. The cylinders containing the oil are covered with cases in metal or sometimes of porcelain. Two drawings of these are shown (*fig.* 1311 and *fig.* 1312). These lamps admit evidently of yet more elegant forms than have been given them. The urn-shaped, from the antique, in very pure taste, is the last introduction of the house above named.

It would be tedious to enumerate the various modifications of form and action to which the oil lamp has been subject, previous to its arrival at what may be deemed its perfect construction by Argand. The discovery of the mode of applying a new principle by this individual not only produced an entire revolution in the manufacture of the article, but threatened with ruin all those whom the patent excluded from participation in the new trade; so much so indeed, that Argand, who had not been apprenticed to the business, was publicly persecuted by the tinners, locksmiths, and ironmongers, who disputed his right by any improvements to infringe the profits of their chartered vocation. 'This invention,' to quote a description of the lamp published some years ago, 'embraces so many improvements upon the common lamp, and has become so general throughout Europe, that it may be justly ranked amongst the greatest discoveries of the age. As a substitute for the candle, it has the advantage of great economy and convenience, with much greater brilliancy; and for the purpose of producing heat, it is an important instrument in the hands of the chemist. We may, with some propriety,' continues this authority, 'compare the common lamp and the candle to fire made in the open air, without any forced method of supplying it with oxygen; while the Argand lamp may be compared to a fire in a furnace, in which a rapid supply of oxygen is furnished by the velocity of the ascending current. This, however, is not the only advantage of this valuable invention. It is obvious that, if the combustible vapour occupies a considerable area, the oxygen of the atmosphere cannot combine with the vapour in the middle part of the ascending column. The outside, therefore, is the only part which enters into combustion; the middle constituting smoke. This evil is obviated in the Argand lamp, by directing a current of atmospheric air through the flame, which, instead of being raised from a solid wick, is produced from a circular one, which surrounds the tube through which the air ascends.

1309



1310



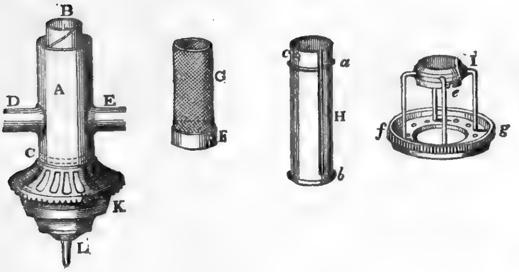
1311

1312

The mechanism of the Argand burner, in its improved state, will be clearly understood from the annexed figures and explanation, which apply equally to each description of the lamps hereafter described.

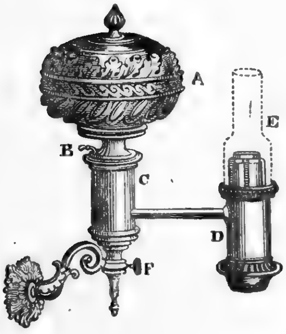
A, *fig.* 1313, is a brass tube, about 3¼ inches in length, and 1¼ inch wide; within this tube is placed another, B, which is soldered fast inside by the flange at C: the space between these tubes contains the oil surrounding the wick, and which, being freely admitted from the reservoir by the side pipes D E, rises in the tubular space, either to a height corresponding with its level in the reservoir, or at least so as to maintain the wick in a state of constant saturation. The tube B is of considerable thickness, having a spiral groove cut about it from top to bottom; F is a metallic ring made to slip over the tube B, it contains a short pin inside, which fits exactly into the spiral groove just mentioned; G is the circular woven cotton wick, the lower end of which is drawn tight upon the neck of the ring; H is a copper tube, with a slit nearly from top to bottom; it admits the ring F, and being dropped over the inner tube B, exactly fits the inside of the wider tube A, by means of a narrow rim near the top at *a*, and another at the bottom *b*; between the upper rim and the margin there is a small projecting pin *c*, which, when the whole apparatus is combined, fits into the cavity *e* of the collar I. To prepare the lamp for use, the tube H is placed between A and B, as just described; the ring F, with its charge of cotton, is next inserted, the pin in the inside falling into the spiral groove, and that on the outside entering the slit in the tube H, which, on being turned about, moves the ring F down upon the screwed inner tube, until the wick only just rises above the superior edges of the tubes, in the interval between which it lies in the oil. In this stage the frame I is placed on the nick in the collar at *e*, falling upon the pin near the top of H; the lower disc *f g*, passing over the tube A, at once presents a convenient support for the glass chimney, and a finger-hold for raising the wick. The central tube is open throughout, communicating, at its lower end, with the brass receptacle K; the latter is perforated at top, to admit the air which, by circulating through the above tube, and the hollow flame which surrounds it, causes the lamp to burn with that peculiar freedom and brilliancy which distinguish the Argand construction. This last-mentioned receptacle likewise catches any small quantity of oil which may pass over the inner tube during the combustion of the wick. L is the brass peg, which fits into the upper part of the pillar, in the table-lamp.

1313



1315

1314



In addition to the endless variety of small portable lamps, the peculiarities of which it would be tedious to particularise, and the merit of which, as compared with those on the Argand principle, consists, for the most part, in their cheapness, the more important articles, and those generally in demand, may be distinguished as fixed or bracket lamps, supended or chandelier lamps, and table or French lamps—all these having burners on the principle above described. The former sort were, previous to the introduction of gas, very common in shops. The globe A (*fig.* 1314), which is sometimes made plain and sometimes embossed, as in the cut, screws off, when the oil is poured in at an opening in the lower part, which is afterwards closed by means of a slide attached to the stem B, and the globe, thus replenished, is inverted and screwed into the part C. When the lamp is used, the stem B is raised a little, and the oil is suffered to flow through the intermediate tube into the cistern D, only at the rate at which it is consumed by the burning of the wick. The peculiar form of the glass chimney is admirably calculated to assist in the more complete combustion of the matter drawn up to the wick when impure oil is used, a desideratum originally in part secured by placing over the central tube, and in the midst of the flame, a circular metal plate, by means of which the ascending column of air was turned out of its perpendicular course, and thrown immediately into that part of the flame where the smoke is formed, and which by this ingenious contrivance is effectually consumed; this application, however, is not necessary, nor the form of much moment, when purified sperm-oil is used. These lamps being usually made to move on a pivot at F, attached to the wall or other support, are very convenient in many situations, as being easily advanced over a desk or counter, and afterwards turned aside when not in use.

The sinumbral lamp having passed out of use need not be described.

The use of spirit lamps followed, and we have the naphtha and camphine lamps of this order. The accompanying woodcut (*fig.* 1315) shows the peculiarity of the camphine lamp, where the reservoir of spirit (turpentine deprived of smell) is far below the burner, to which it ascends by capillary attraction, through the tubes of the cotton wick. Lamps to burn naphtha (*Belmontine*, &c.) are constructed on the same principle, as are all the paraffine and mineral-oil lamps.

One of the best oil lamps is that known as Carcel's lamp.

In this lamp the oil is raised through tubes by clockwork, so as continually to overflow at the bottom of the burning wick; thus keeping it thoroughly soaked, while the excess of the oil drops into the cistern below. Lamps of this description will burn most satisfactorily for many years; but it can hardly be trusted in the hands of a servant, and when it gets at all deranged, it must be sent to its constructor, in Paris, to be repaired. The light of this lamp, when furnished with an appropriate tall glass chimney, is very brilliant, though not perfectly uniform; since it fluctuates a little, but always perceptibly to a nice observer, with the alternating action of the pump-work; becoming dimmer after every successive jet of oil, and brighter just before its return. The flame, moreover, always flickers more or less, owing to the powerful draught, and rectangular reverberatory shoulder of the chimney. The mechanical lamp is, however, remarkable for continuing to burn, not only with unabated but with increasing splendour for 7 or 8 hours; the vivacity of the combustion increasing evidently with the increased temperature and fluency of the oil, which, by its ceaseless circulation through the ignited wick, gets eventually pretty warm. In the comparative experiments made upon different lights by the Parisian philosophers, the mechanical lamp is commonly taken as the standard. It is not entitled to this pre-eminence, for it may be made to emit very different quantities of light, according to differences in the nature and supply of the oil, as well as variations in the form and position of the chimney.

The following experiments by Dr. Ure are well worth preserving:—

The great obstacle to the combustion of lamps lies in the viscidity, and consequent sluggish supply, of oil to the wicks; an obstacle nearly insuperable with lamps of the common construction during the winter months. The relative viscidity or relative fluency of different liquids at the same temperature, and of the same liquid at different temperatures, has not, I believe, been hitherto made the subject of accurate researches. I was, therefore, induced to make the following experiments with this view.

Into a hemispherical cup of platinum, resting on the ring of a chemical stand, I introduced 2,000 water-grain measures of the liquid whose viscidity was to be measured, and ran it off through a glass siphon, $\frac{1}{8}$th of an inch in the bore, having the outer leg $3\frac{1}{4}$ inches, and the inner leg 3 inches long. The time of efflux became the measure of the viscidity; and of two liquids, if the specific gravity and consequent pressure upon the siphon were the same, that time would indicate exactly the relative viscidity of the two liquids. Thus, oil of turpentine and sperm-oil have each very nearly the same density; the former being, as sold in the shops, $=0{\cdot}876$, and the latter from 0·876 to 0·880, when pure and genuine. Now I found that 2,000 grain-measures of oil of turpentine ran off through the small siphon in 95 seconds, while that quantity of sperm-oil took 2,700 seconds, being in the ratio of 1 to $28\frac{1}{2}$; so that the fluency of oil of turpentine is $28\frac{1}{2}$ times greater than that of sperm-oil. Pyroxilic spirit, commonly called naphtha, and alcohol, each of specific gravity 8·125, were found to run off respectively in 80 and 120 seconds; showing that the former was 50 per cent.

more fluent than the latter. Sperm-oil, when heated to 265° Fahr., runs off in 300 seconds, or $\frac{1}{5}$th of the time it took when at the temperature of 64°. Southern whale oil, having a greater density than the sperm-oil, would flow off faster were it not more viscid. 2,000 grain-measures of water at 60° run off through the said siphon in 75 seconds, but when heated to 180° they run off in 61 seconds. Concentrated sulphuric acid, though possessing the great density of 1·840, yet flows off very slowly at 64°, on account of its viscidity, whence its name of oil of vitriol. 2,000 grain-measures of it took 660 seconds to discharge.

For a continuation of this subject, and a further description of lamps of various kinds, see also SILBER LIGHT ; SAFETY LAMP.

LAMPIC ACID. *Syn.* Aldehydic acid ; Acetylous acid. (*Acide lampique*, Fr.) If a little ether be placed at the bottom of a glass, and some spongy platinum attached to a wire of the same metal be ignited and suspended about an inch from the fluid, it will glow and continue to do so for a long time. On the other hand, if a spiral of platinum wire be placed over the wick of a spirit-lamp, and the latter be first ignited and then blown out, the wire will continue at a red heat until all the spirit is exhausted. Numerous sesquioxides, when placed warm on wire-gauze over capsules containing alcohol, will glow in the same manner. Under all these circumstances, a powerful odour resembling aldehyde is evolved, which strongly affects the eyes. If this experiment be made in such a manner that the volatile product may be condensed, it will be found to be strongly acid. It is powerfully reducing in its tendency, and if heated with the oxides of silver or gold, converts them into the metallic state, and the liquid is found to contain acetic acid and resin of aldehyde. If, however, the acid liquid be only very gently warmed with oxide of silver, a portion of the latter is dissolved ; but when baryta is added to precipitate the silver as oxide, and the fluid is warmed, the metal instead of the oxide comes down, and the fluid, when tested for the nature of the acid, is found to contain nothing but acetate of baryta. These phenomena are explained by some chemists by supposing the fluid to contain an acid which they, following the late Professor Daniell, call the lampic, and supposed to contain $C^4H^4O^3$ ($\mathbf{C^4H^8O^3}$). When lampic acid is treated first with oxide of silver, and then with baryta-water, and heated, they consider that the oxygen of the oxide of silver is transferred to the lampic acid, and converting it into acetic acid, which combines with the baryta, while the metallic silver is precipitated. The following equation explains the reaction supposed to take place:—

$$\underbrace{C^4H^4O^3}_{\text{Lampic acid.}} + BaO + AgO = \underbrace{C^4H^3O^3,BaO}_{\text{Acetate of baryta.}} + Ag + HO.$$

$$\mathbf{C^4H^8O^3 + BaO + Ag^2O = (C^2H^3O^2)^2Ba + Ag^2 + H^2O.}$$

The conversion of the lampic acid into acetic acid is therefore attributed to the oxidising tendency of the oxide of silver. Those who regard the decomposition from the above point of view, consider lampic acid to be acetylous acid, that is to say, to bear the same relation to acetylic acid (acetic acid) that sulphurous acid does to sulphuric acid.

LAMBSKINS. With the fleece on, these are extensively used for clothing, for door-mats, and the like. *Prussian lambskins* are used for linings, for coat collars and cuffs. *Astracan lamb*, which is a rich, glossy, black skin, with short fur, is used for many ornamental costumes. *Hungarian lamb:* this skin forms the national coat of Hungary. *Spanish lamb:* the short jacket of the Spaniard is made of this skin. It is said that upwards of a million lambskins are imported annually into this country for glove-making.

LANARKITE. A sulphato-carbonate of lead occurring at Leadhills in Lanarkshire, whence the name.

LANCE WOOD. *Uvaria lanceolata* or *Guatteria virgata.* This wood is imported from Jamaica and Cuba, in long poles from 3 to 6 inches diameter. Lance wood is paler in colour than box ; it is selected for elastic works, as gig-shafts, archery bows, springs, &c. These are bent into the required form by boiling or steaming. Surveyor's rods, ordinary rules, and billiard cues are made of lance wood.

LANDER. In mining, the man who attends at the mouth of the shaft to receive the 'kibble of ore' as it reaches the surface.

LANGITE. A basic sulphate of copper, from Cornwall, described a few years ago by Prof. Maskelyne.

LANTHANUM. A metal discovered by Mosander in 1841. It occurs associated with didymium and cerium, in certain rare Swedish minerals.

LAPIDARY, *Art of.* The art of the lapidary, or that of cutting, polishing, and engraving gems, was known to the ancients, many of whom have left admirable specimens of their skill. The Greeks were passionate lovers of rings and engraved stones; and the most parsimonious among the higher classes of the Cyrenians are said to have worn rings of the value of ten minæ (about 30*l.* of our money). By far the greater part of the antique gems that have reached modern times may be considered as so many models for forming the taste of the student of the fine arts, and for inspiring his mind with correct ideas of what is truly beautiful. With the cutting of the diamond, however, the ancients were unacquainted, and hence they wore it in its natural state. Even in the middle ages, this art was still unknown; for the four large diamonds which enrich the clasp of the imperial mantle of Charlemagne, as now preserved in Paris, are uncut, octahedral crystals. But the art of working diamonds was probably known in Hindostan and China in very remote periods. After Louis de Berghen's discovery, in 1476, of polishing two diamonds by their mutual attrition, all the finest diamonds were sent to Holland to be cut and polished by the Dutch artists, who long retained a superiority, now no longer admitted by the lapidaries of London and Paris. See DIAMOND.

The operation of gem-cutting is abridged by two methods: 1, by cleavage; 2, by cutting off slices with a fine wire, coated with diamond-powder, and fixed in the stock of a hand-saw. Diamond is the only precious stone which is cut and polished with diamond-powder, soaked with olive oil upon a mill plate of very soft steel.

Oriental rubies, sapphires, and topazes, are cut with diamond-powder soaked with olive oil, on a copper wheel. The facets thus formed are afterwards polished on another copper wheel, with tripoli, tempered with water.

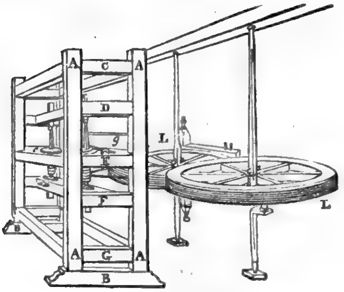
Emeralds, hyacinths, amethysts, garnets, agates, and other softer stones, are cut at a lead wheel, with emery and water; and are polished on a tin wheel with tripoli and water, or, still better, on a zinc wheel, with putty of tin and water.

The more tender precious stones, and even the pastes, are cut on a mill-wheel of hard wood, with emery and water; and are polished with tripoli and water on another wheel of hard wood.

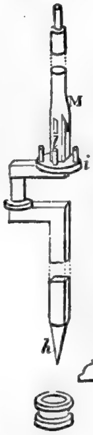
Since the lapidary employs always the same tools, whatever be the stone which he cuts or polishes, and since the wheel discs alone vary, as also the substance he uses with them, we shall describe, first of all, his apparatus, and then the manipulations for diamond-cutting, which are applicable to every species of stone.

The lapidary's mill, or wheel, is shown in perspective in *fig.* 1316. It consists of a strong frame made of oak carpentry, with tenon and mortised joints, bound together with strong bolts and screw nuts. Its form is a parallelopiped, of from 8 to 9 feet long, by from 6 to 7 feet high; and about 2 feet broad. These dimensions are large enough to contain two cutting wheels alongside of each other, as represented in the figure.

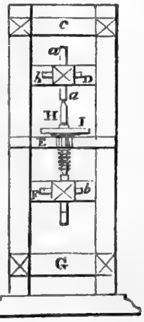
1316



1317



1318



Besides the two sole bars B B, we perceive in the breadth, 5 cross bars, C, D, E, F, G. The two extreme bars C and G, are a part of the frame-work, and serve to bind it. The two cross-bars D and F, carry each in the middle of their length, a piece of wood as thick as themselves, but only 4½ inches long (see *fig.* 1316), joined solidly by mortises and tenons with that cross-bar as well as with the one placed opposite on the other parallel face. These two pieces are called *summers* (lintels); the one placed at D is the upper; the one at F the lower.

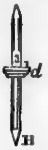
In *fig.* 1318 this face is shown inside, in order to explain how the mill wheel is placed and supported. The same letters point out the same objects, both in the preceding and the following figures.

In each of these *summers* a square hole is cut out, exactly opposite to the other in which are adjusted by friction a square piece of oak, *a a*, *fig.* 1318, whose extremities are perforated with a conical hole, which receives the two ends of the arbor H of the wheel I, and forms its socket. This square bar is adjusted at a convenient height by a double wooden wedge, *b b*. The cross-bar in the middle E, supports the table *c c*, a strong plank of oak. It is pierced with two large holes, whose centres coincide with the centres of the conical holes hollowed out at the end of the square pins. These holes of about 6 inches diameter each, are intended to let the arbor pass freely through, bearing its respective wheel. (See one of these holes at I, in *fig.* 1320 below).

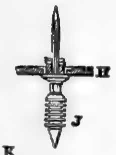
Each wheel is composed of an iron arbor H, *fig.* 1318, of a grinding wheel I, which differs in substance according to circumstances, as already stated, and of the pulley J, furnished with several grooves (see *fig.* 1320), which has a square fit upon the arbor. The arbor carries a collet *d*, on which are four iron pegs or pins that enter into the wheel to fasten it.

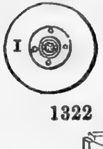
The wheel plate, of which the ground plan is shown at K, is hollowed out towards its centre to half its thickness; when it is in its position on the arbor, as indicated in *fig.* 1320, a washer or ferrule of wrought iron is put over it, and secured in its place by a double wedge. In *fig.* 1320 the wheel-plate is represented in section, that the connection of the whole parts may be seen.

1319



1320





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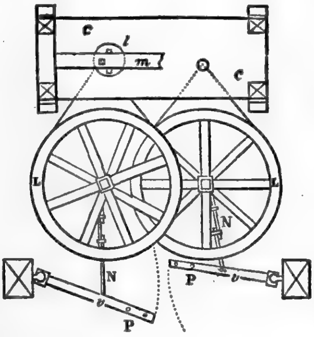

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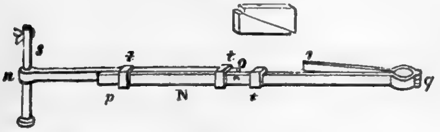


A board *g* (see *fig.* 1316 and *fig.* 1324) about 7½ inches high, is fixed to the part of the frame opposite to the side at which the lapidary works, and it prevents the substances made use of in the cutting and polishing from being thrown to a distance by the centrifugal force of the wheel-plate.

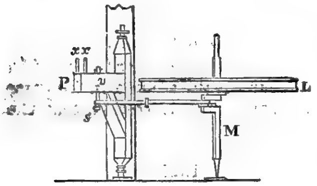
Behind the apparatus is mounted for each grinding-plate, a large wheel L (see *fig.* 1316), similar to a cutler's, but placed horizontally. The wheel is grooved round its circumference to receive an endless cord or band, which passes round one of the grooves of the pulley J, fixed below the wheel-plate. Hence, on turning the fly-wheel L, the plate revolves with a velocity relative to the velocity communicated to the wheel L, and to the difference of diameter of the wheel L, and the pulley J. Each wheel L, is mounted on an iron arbor, with a crank (see M, *fig.* 1317).

The lower pivot of the arbor *h* is conical, and turns in a socket fixed in the floor. The great wheel L rests on the collet *i*, furnished with its 4 iron pins, for securing the connection. Above the wheel an iron washer is laid, and the whole is fixed by a double wedge, which enters into the mortise *l*, *fig.* 1317.

Fig. 1321 exhibits a ground-plan view of all this assemblage of parts, to explain the structure of the machine. Everything that stands above the upper *summer-bar* has been suppressed in this representation. Here we see the table *c c*; the upper *summer m*; the one-wheel plate *l*, the other having been removed to show that the endless cord does not cross; the two large wheels L L, present in each machine, the crank bar N, seen separate in *fig.* 1322, which serves for turning the wheel L. This bar is formed of three iron plates *n*, *o*; *p*, *q*; and *q*, *r* (*fig.* 1322). The first is bent round at the point *n*, to embrace the stud *s*; the second *p q*, is of the same breadth and thickness as the first; and the third, is adjusted to the latter with a hinge joint, at the point *q*, where they are both turned into a circular form, to embrace the crank M. When all these pieces are connected, they are fixed at the proper lengths by the buckles or square rings *t t t*, which embrace these pieces, as is shown in *fig.* 1322.

The stud *s*, seen in *fig.* 1322, is fixed to the point *v*, by a wedge-key upon the arm P, represented separately, and in perspective, in *fig.* 1323. The labourer seizes the two upright pegs or handles *x x*; by the alternate forward and backward motion of his arm, he communicates the same motion to the crank-rod, which transmits it to the crank of the arbor M, and impresses on the arbor, and the wheel which it bears, a rotatory movement.

1323



1324

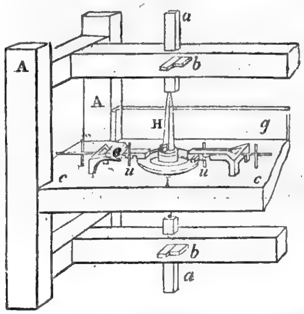
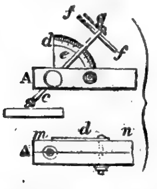


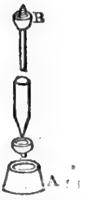
Fig. 1324 shows piece-meal and in perspective a part of the lapidary's wheel-mill. There we see the table *c c*, the grind plate I, whose axis is kept in a vertical position by the two square plugs *a a*, fixed into the two *summers* by the wedges *b b*. On the two sides of the wheel-plate, we perceive an important instrument called a *dial*, which serves to hold the stone during the cutting and polishing. The instrument has received lately important ameliorations, to be described in *fig.* 1325. The lapidary holds this instrument in his hand, he rests upon the iron pins *u u*, fixed in the table lest he should be affected by the velocity of the revolving wheel-plate. He loads it sometimes with weights *e e*, to make it take better hold of the grinding-plate.

Fig. 1325, shows an improvement made by one of the most expert lapidaries of Geneva, whereby he cuts and polishes the facet with extreme regularity, converting it into a true dial. Each of the two jaws bears a large conchoidal cavity, into which is fitted a brass ball, which carries on its upper part a tube *e*, to whose extremity is fixed a dial-plate *f f*, engraved with several concentric circles, divided into equal parts, like the toothed-wheel cutting engine-plate, according to the number of facets to be placed in each cutting range. The tube receives with moderate friction the handle of the cement-rod, which is fixed at the proper point by a thumb-screw, not shown in the figure, being concealed by the vertical limb *d*, about to be described.

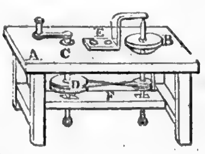
1325



1326



1327



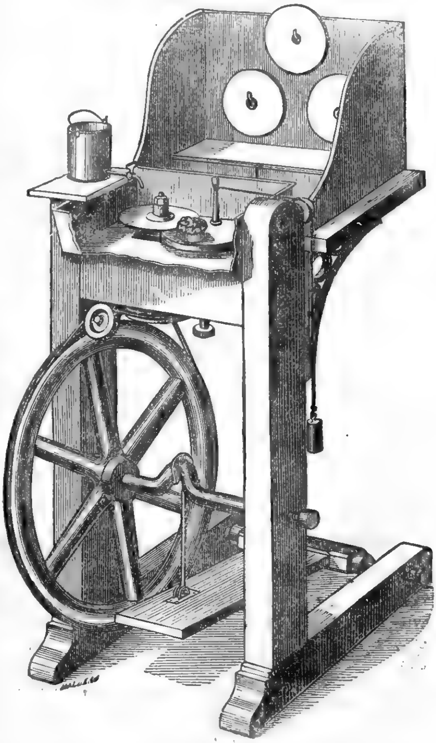
A needle or index *g*, placed with a square fit on the tail of the cement-rod, marks by its points the divisions on the dial-plate *f. f.* On the side *m n*, of the jaw A, there is fixed by two screws, a limb *d*, forming a quadrant, whose centre is supposed to be at the centre of the ball. The quadrant is divided as usual into 90 degrees, whose highest point is marked 0, and the lowest would mark about 70; for the remainder of the arc down to 90 is concealed by the jaw. The two graduated plates are used as follows:—

When the cement-rod conceals zero or 0 of the limb, it is then vertical, and serves to cut the table of the brilliant; or the point opposite to it, and parallel to the table, On making it slope a little; 5 degrees, for example, all the facets will now lie in the same zone provided that the inclination be not allowed to vary. On turning round the cement-rod and the index *g* marks the divisions so that by operating on the circle with 16 divisions, stopping for some time at each, 16 facets will have been formed, of perfect equality, and at equal distances, as soon as the revolution is completed.

In cutting the stones, they are mounted on the cement-rod B, *fig.* 1326, whose stem is set upright in a socket placed in a middle of a sole piece at A, which receives the stem of the cement-rod. The head of the rod fills the cup of A. A melted alloy of tin and lead is poured into the head of the cement-rod, in the middle of which the stone is immediately plunged; and wherever the solder has become solid, a portion of it is pared off from the top of the diamond, to give the pyramidal form shown in the figure at B.

There is an instrument employed by the steel polishers for pieces of clock-work, and by the manufacturers of watch-glasses for polishing their edges. It consists of a solid oaken table, *fig.* 1327. The top is perforated with two holes, one for passing through the pulley and the arbor of the wheel-plate B, made either of lead or of hard wood, according to circumstances; and the other C for receiving the upper part of the arbor of the large pulley D. The upper pulley of the wheel-plate is supported by an iron prop E, fixed to the table by two wooden screws. The inferior pivots of the two pieces are supported by screw sockets, working in an iron screw-nut sunk into the summer-bar F. The legs of the table are made longer or shorter, according as the workman chooses to stand or sit at his employment. Emery with oil is used for grinding down, and tin-putty or colcothar for polishing. The workman lays the piece on the flat of the wheel-plate with one hand, and presses it down with a lump of cork, while he turns round the handle with the other hand.

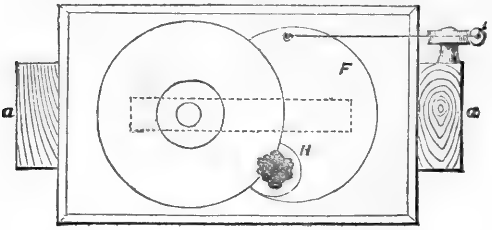
1328

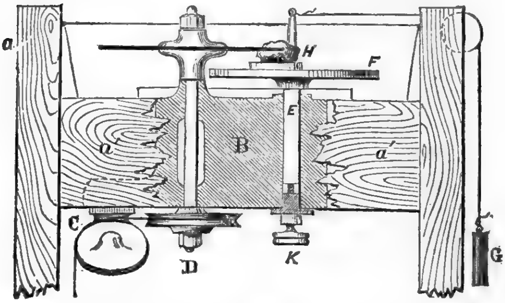


A very convenient form of apparatus has been devised by Mr. James B. Jordan, and manufactured by Messrs. Cotton and Johnson, of Grafton Street, Soho, for the purpose of preparing thin sections of minerals, rocks, and other hard substance for microscopical observation. This machine is represented in *figs.* 1328, 1329, and 1330. It consists of a wooden frame-work, *a a*, supporting a crank-axle and driving-wheel, two feet diameter; the top part of this frame consists of two cross-pieces *a′*, fixed about an inch apart, as in the bed of an ordinary turning-lathe; into the slot between them is placed a casting B, carrying the bracket for the angle-pulleys C; this casting is bored to receive the spindle D, which, by means of the treadle, is made to revolve at the rate of 400 or 500 revolutions per minute. It is also bored to receive another spindle E, to the top of which is fixed a metal plate F, for carrying the small cup H, to which the specimen is attached by means of prepared wax. This means of mechanically applying the work to the slicer is far preferable to holding it in the hand in the ordinary way; the requisite pressure against the cutting disc is regulated by the weight G, and the thickness of the slice by the thumb-screw K, on which the spindle rests. By this means it is possible to cut tolerably thin and parallel slices, of from $\frac{1}{10}$th to $\frac{1}{8}$th of an inch in thickness; the thinness of course varying according to the strength of the rock which is being operated upon. The slitting disc is made of soft iron, eight inches diameter, and about $\frac{1}{50}$th of an inch in thickness, and it is fixed on the spindle D, between two brass plates 4 inches diameter, charged with diamond-powder in the usual way.

The slices are still further reduced in thickness by grinding with fine emery and water on a lead 'lap,' which is made to revolve on the spindle D. The lap is 8 inches diameter, and about $\frac{3}{8}$ths of an inch thick in the centre, cast with rounded edges and

1329





1330

slightly convex sides; this form facilitates the grinding of a uniform thinness, there being always a tendency on a flat surface (which soon wears hollow) for the edges of the section to grind away before it is sufficiently thin. One side of the section can easily be ground and finished by holding in the hand; and this being done, it must be cemented with hard Canada balsam to a small square of plate glass, in order to grind the other side, which operation must be carefully carried on until the structure appears distinct and well defined. The finish requisite is best given by careful rubbing on the flat surface of a hone-stone until all traces of the lines of grinding and scratches are removed.

Thin sections for microscopic study are then usually re-mounted in Canada balsam under a glass cover in the ordinary way.

LAPIS LAZULI. A silicate of soda, lime, and alumina, with the sulphide of iron and sodium in minute quantities. This beautiful mineral is found in crystalline limestone of a greyish colour, on the banks of the Indus, and in granite in Persia, China, and Siberia.

The finest varieties are highly esteemed, being employed in the manufacture of costly vases. It was also the source from which the beautiful pigment ultramarine, was obtained, but this colour is now prepared artificially at a very cheap rate. See ULTRAMARINE.

LAPIS OLLARIS, or *Pot-stone.* An impure form of steatite.

LAPS. Metal polishing-wheels. Metal wheels or laps made of nearly every metal and alloy in common use, have been more or less employed in the mechanical arts as vehicles for the application of several of the polishing-powders. But of all laps, notwithstanding their variety, those of lead, slightly alloyed, and supplied with powdered emery, rendered the most conspicuous service. Generally the plane, or flat surface of the lap, is employed; at other times the cylindrical edge, as by cutlers; but the portion actually used in either case is called the *face* of the lap. There are several kinds of laps. The lap is in some cases a thin disc of metal, fixed by means of a screwed nut against a shoulder on the spindle, but it is better with lead laps to employ an iron plate cast full of holes to support the softer metal. The casting mould may in this case be either an iron disc, with a central screw to fix the iron centre plate at the time of pouring, or the mould may be made of sand and in halves, after the usual manner of the foundry.

In either case the iron plate should be made as hot as the fluid metal, which, by entering the holes, becomes firmly united to the iron, especially if the holes are largest on the reverse side, or that away from the lead.—*Holtzapffel.*

Lap is also a roll or sliver of cotton for feeding the cards of a spinning machine.

LARD. The fat of the pig.

LARD OIL. Lard being subjected to a pressure, an oil, *oleine*, is expressed, *stearine* being left. This lard oil is much used for lubricating machinery, and it has been employed for the adulteration of olive oil.

LARDERELLITE. A borate of ammonia, from the boracic-acid lagoons of Tuscany.

LASKS. All Indian cut stones are called *lasks.* They are in general ill-shaped or irregular in their form, their depth ill-proportioned, and the table, or face, seldom in the centre of the stone, sometimes too broad or too small, and none properly polished. The chief thing regarded is saving the size and weight of the stone. These stones are always new wrought when brought to Europe.

LATHE-CORDS. Cords for turning lathes. These cords are made of intestines of horses, cleaned and prepared by the separation of the mucous membrane in the manner described under GOLD BEATERS' SKIN. A wooden ball, armed in its lower part with four cutting blades, at equal distances from each other, is fixed by an upright piece of wood to a bench. The end of an intestine is then drawn over this ball, and as the gut is pulled downwards it is divided into four equal bands or strips.

Four or eight of these strips, according to the thickness which it is intended to give to the cord, are tied with a peculiar knot to one end of a thick piece of cord. The end is passed around a peg introduced into a hole in a solid post, to the side of which a number of pegs are attached. At a distance of ten or eleven yards from the first one, another post is fixed, similarly provided with pegs, and over one of these latter the middle of the assemblage of strips is passed, the other end being brought back, and attached to the first peg by means of another knotted cord. The tied end of the strisp is then attached to the wheel by a hook connected with the *whirl*, which is made to revolve until the strips are sufficiently twisted. The twisted end is then kept stretched by attaching it to the peg, and any projecting filaments are cut off. After being stretched for some time, the cords are then twisted again, and a third and a fourth time are twisted by hand, being each time rubbed with and drawn through a bunch of moistened horsehair after the twisting, and again stretched out between the two posts. If the cord is not smooth and even after the twisting is completed, it is made so by rubbing with a piece of dog-skin. It is then dried, and by some makers is exposed to the vapours of sulphur. At last the ends are cut off, and the cord is rolled in a coil.

In order to avoid the putrid emanations, from the intestines, which are generally in an incipient state of decomposition, Labarraque recommends to clean them at once, turn the inside out, and put them to soak over night in a cask containing, for fifteen or twenty intestines, chloride of potash, at 13° or 18°, 1 lb.; water, 4 gallons. The mucous membrane is ready to be detached the next day; and after its removal, and a thorough washing, the intestines can at once be prepared, as has been already described.

LATH WOOD. The outside cuttings of fir-trees, used for being split into laths.

LATTEN is a somewhat antiquated term, which was applied to several kinds of sheet metal. 'Mines of *latten*, whatever may have been meant by the word, are mentioned in the time of Henry VI., who made his chaplain, John Botteright, comptroller of all his mines of gold, silver, copper, *latten*, lead, within the counties of Devon and Cornwall.' Is tin meant by the term?—*Watson's Chemical Essays.*

In the reigns of Henry VIII. and Edward VI., several acts of parliament were passed, prohibiting the exportation of brass, copper, *latten*, bell-metal, gun-metal, schrof metal, &c. Windows framed with lead are called *lattice* windows in the West of England.

The term is now applied to sheet or plate brass. *Black latten* is rolled sheets; *shaven latten* is in *thinner sheets*; and *roll latten* is polished on both sides.

LAUGHING GAS. The popular name of *nitrous oxide* or *nitrogen monoxide*, NO (**N^2O**). It is best prepared by heating solid nitrate of ammonia, this salt being resolved by heat into laughing gas and water. The gas, when inhaled, produces a peculiar intoxicating effect, usually without being followed by any ill consequences. Of late years laughing gas has been largely used by dentists as an anæsthetic. Care, however, is needed in administering it, as it may produce serious results on individuals suffering from certain affections of the heart.

LAUMONTITE, or *Efflorescing zeolite.* A hydrous silicate of alumina and lime, occurring in cavities in amygdaloidal trap rocks and in metalliferous veins. It is common in some of the copper deposits of Lake Superior.

LAUNDER. A miner's term for a wooden tube or gutter to convey water. A long shallow trough, carrying off the ore from the stamps.

LAUREL OIL. This oil is known also under the name of '*oil of bays*,' and is obtained from either the fresh or dried berries of the *bay tree* (*Laurus nobilis*), which grows principally in the south of Europe; and is also cultivated in our gardens, the leaves being used by the cook on account of their flavour. The berries were analysed by Bonastre in 1824, and amongst other things, were volatile oil, 0·8, laurin (camphor of the bay berry), 1·0, and fixed oil, 12·8, in 100 parts of the berries. Duhamel states that the fixed oil is obtained from the fresh and ripe berries by bruising them in a mortar, boiling them for three or four hours in water, and then pressing them in a sack. The expressed oil is mixed with the decoction, and on cooling is found floating on the surface of the water. When the dried berries are used, they are first subjected to the vapour of water until they are well soaked, and are then rapidly pressed between heated metallic plates. By the latter process they yield one-fifth of their weight of oil. It is imported in barrels from Trieste. It has a butyraceous consistence and a granular appearance. Its colour is greenish, and its odour like that of the berries. Cold alcohol extracts from it the essential oil and green colouring matter, leaving the *lauro-stearine*, which composes the principal part of it. With alkalis it forms soaps. But its principal use is in medicine, and more particularly in veterinary medicine. It has been used as a stimulating liniment in sprains and bruises, and in paralysis.

Native Oil of Laurel (*Hancock*); *Laurel Turpentine* (*Stenhouse*).—Imported from Demerara; obtained by incisions in the bark of a large tree, called by the Spaniards '*Azeyte de sassafras*,' growing in the vast forests between the Orinoco and the Parime. This oil is transparent, slightly yellow, and smells like turpentine, but more agreeable, and approaching to oil of lemons. Its specific gravity at 50° Fahr. is 0·8645. It consists of two or more oils isomeric with each other, and with oil of turpentine. Its colour is due to a little resin. It is an excellent solvent for caoutchouc.—*Pereira.*

LAURIC ACID. An acid obtained from the fat of the bay tree (*Laurus nobilis*), and from the oil of pichurim beans (*Faba pichurim maj.*)

LAURITE. A sulphide of osmium and ruthenium, found in the platinum washings in Borneo.

LAVA. The ejected matter of volconoes. 'The stone which flows in a melted state from a volcano.'—*Lyell.* M. Abich obtained from the Etna lava of 1669, 48·83 silica. He found the lava to consist of 54·80 labradorite, 34·16 augite, 7·98 olivine, and 3·08 magnetic iron.

Bischoff gives the following two analyses of lava:—

	Hecla	Etna
Silica	54·76	49·63
Alumina	13·61	22·47
Peroxide of iron	15·60	10·80
Lime	6·14	9·05
Magnesia	1·35	2·68
Potash	3·41	3·07
Soda	1·21	0·98

LAVA-WARE. A peculiar stoneware, manufactured and coloured to assume the semi-vitreous appearance of lava.

LAVER. *Porphyra laciniata* and *Ulva latissima.* See ALGÆ.

LAVENDER, OIL OF. See PERFUMERY.

From the flowers of the *Lavandula spicata* the oil of spike is obtained, which is used by painters on porcelain, and by artists in the preparation of some varnishes.

LAWN. A fine linen fabric.

LAZULITE (Eng. and Fr.; *Lazulith*, Ger.), from an Arabic word, *azul*, meaning *heaven*. It is a blue vitreous mineral, found massive and crystalline, traversing clay slate, and sometimes associated with spathic iron; spec. grav. 2·76 to 2·94; scratches glass; affords a little water by calcination; fusible into a white glass; dissolves in acids with loss of colour; the solution leaves an alkaline residuum, after being treated with carbonate of ammonia, filtered, evaporated, and calcined. By analysis it is found to consist of:—

	1	2
Phosphoric acid	43·88	46·79
Alumina	31·77	27·10
Protoxide of iron	8·90	7·10
Magnesia	9·89	11·87
Water	5·56	7·12

LEAD. (*Plomb*, Fr.; *Blei*, Ger.) This metal appears to have been known at a very early period. It is mentioned by Moses, as a metal in common use. Job describes mining for lead, and the metallurgic processes of refining and separating silver from lead are very clearly described by both Job and Jeremiah. Lead has a bluish-grey colour, and, when recently cut, it exhibits considerable lustre, which, however, it speedily loses. It is one of the softest of the ordinary metals, is easily cut with a knife, may be scratched with the nail, and marks paper with a grey stain. Lead is malleable, and may be beaten into thin leaves, but these are of very imperfect tenacity; hence, it cannot be drawn into thin wire; a wire of $\frac{1}{12}$th of an inch in diameter will not support 20 lbs.

If lead be prepared in a very finely divided state, it is *pyrophoric*. This is usually prepared from the tartrate of lead, by heating it in a glass tube as long as any fumes are evolved; consequently, it is finely-divided lead, combined with some carbon. As soon as the fumes cease, the tube must be closed at the blowpipe-lamp. If at any time the tube is broken, and the powder scattered in the air, it burns with a red flash.

If lead is heated in closed vessels, it fuses at 635° F. (335° C.), and at a red heat, it gives off vapours. If fused lead is allowed to cool slowly, it crystallises in a somewhat peculiar manner; the crystals are referrible to the cubic system, but they group themselves in a very complicated and interesting way. By the electro-chemical action of zinc on a solution of the acetate of lead, crystals of that metal are obtained in an arborescent form. This experiment is usually spoken of as the formation of *Saturn's tree*, Saturn being the alchemic name for this metal.

When fused in the air, lead oxidises rapidly, and it becomes covered with an iridescent pellicle, often of great beauty. It then passes into a yellow powder (litharge), protoxide of lead.

Pure lead is not affected by perfectly pure water free from air; but if air be present, the metal is oxidised at its expense, and the oxide thus formed, combining with carbonic acid, is deposited on the lead in minute crystals as a basic carbonate of lead. The water will then be found to contain lead in solution, and such waters drawn from impure cisterns often produce very distressing consequences. If the water contains any sulphates, the lead is thrown down as a sulphate of lead, which is insoluble.

The Ores of Lead.

1. *Native lead.*—Mr. Greg appears to doubt the existence of native lead in this country. He says, however, 'Native lead has been recently discovered in undoubtedly genuine specimens in the province of Guanaxuato in Mexico.' Some equally genuine specimens of native lead have been found in the Grassington mines and examined by the Editor; these are in the cabinets of the Duke of Devonshire, and of the late Stephen Eddy, and it is now we presume in the possession of his son.

2. *Minium. Native oxide of lead.*—This rare ore has been found in Anglesea, at Alston Moor, the Snailbeach Mine in Shropshire, at Grassington, the Leadhills in Scotland, and Wicklow in Ireland. Its composition is—lead, 90·66, oxygen, 9·34.

3. *Cerussite. Carbonate of lead. White Lead ore* (*Bleispath*, Ger.).—This ore occurs in crystals, in fibrous, compact, and earthy masses. It is found at several of the lead mines of Cornwall and Devonshire; remarkably fine specimens have been obtained from Frank Mills Mines in Devonshire. one of which is in the Museum of Practical Geology. In nearly all the mines producing the ores of lead, *cerussite* is formed, varying much in its character with the different conditions under which it has been formed.

This ore, in its purest state, is colourless and transparent like glass. It may be recognised by the following characters: Its specific gravity is from 6 to 6·7; it dissolves with more or less ease, and with effervescence, in nitric acid; becomes immediately black by the action of sulphuretted hydrogen, and melts on charcoal before the blowpipe into a button of lead. According to Klaproth, the carbonate of Leadhills contains 82 parts of oxide of lead, and 16 of carbonic acid, in 98 parts. This mineral is tender, scarcely scratches calcspar, and breaks easily with a waved conchoidal fracture. It possesses the double refracting property in a very high degree; the double image being very visible on looking through the flat faces of the prismatic crystals. Its crystalline forms are very numerous, and are referrible to the rhombic system. It is also found in an earthy state.

4. *Anglesite. Sulphate of lead*, or *Vitreous lead* (*Bleivitriol*, Ger.).—This mineral closely resembles carbonate of lead; so that the external characters are inadequate to distinguish the two. But the following are sufficient. It does not effervesce with nitric acid; it is but feebly blackened by sulphuretted hydrogen; it first decrepitates and then melts before the blowpipe into a transparent glass, which becomes milky as it cools. By the combined action of heat and charcoal, it passes first into a red pulverulent oxide,

and then into metallic lead. It consists, according to Klaproth, of 71 oxide of lead, 25 sulphuric acid, 2 water, and 1 iron. The prevailing form of crystallisation is the rectangular octahedron, whose angles and edges are variously modified. This mineral was first recognised in Anglesea, hence its name. It was found in the Channel Islands at Sark Mine, and is occasionally met with in the Leadhills and at Wanlockhead in Scotland, at Glemalure in Wicklow, and at Ballycorus Mine, Co. Dublin.

5. *Phosphate of lead. Pyromorphite.*—This, like all the combinations of lead with an acid, exhibits no metallic lustre, but a variety of colours. Before the blowpipe, upon charcoal, it melts into a globule externally crystalline, which by a continuance of the heat, with the addition of iron and boracic acid, affords metallic lead. Its constituents are 80 oxide of lead, 18 phosphoric acid, and 1·6 hydrochloric acid, according to Klaproth's analysis of the mineral from Wanlockhead. The crystalline forms are derived from an obtuse rhombohedron. Phosphate of lead is a little harder than white lead; it is easily scratched, and its powder is always grey. Its specific gravity is 6·9. It has a vitreous lustre, somewhat adamantine. Its lamellar texture is not very distinct; its fracture is wavy, and it is easily frangible. The phosphoric and arsenic acids being, according to M. Mitscherlich, isomorphous bodies, may replace each other in chemical combinations in every proportion, so that the phosphate of lead may include any proportion, from the smallest fraction of arsenic acid to the smallest fraction of phosphoric acid, thus graduating indefinitely into arsenate of lead. The yellowish variety indicates, for the most part, the presence of arsenic acid. It is found in Cornwall, Devonshire, Yorkshire, Derbyshire, and Cumberland, very fine specimens being found in the Alston Moor mines.

6. *Arsenate of lead. Mimetesite.*—The name is derived from *μιμητής*, *imitator*, the species so nearly resembling pyromorphite. The colour of this ore varies from straw-yellow and wax-yellow to brown, reddish-brown, orange, yellow, and red. Before the blowpipe, on charcoal, it emits arsenical fumes, and yields a bead of lead. The analysis by Dufrenoy gives the following as its composition:—

Arsenate of lead	84·55
Phosphate of lead	4·50
Chloride of lead	9·05

At Drygill, in Cumberland, this ore has been met with in sufficient abundance to be worked to some extent as an ore of lead. The mimetesite from this mine was at one time used in the manufacture of flint-glass, to which it gave great brilliancy. The form of the arsenate of lead, when it is crystallised, is a prism with six faces, of nearly the same dimensions as that of phosphate of lead. When pure, it is reducible upon charcoal, before the blowpipe, into metallic lead, with the copious exhalation of arsenical fumes; but only in part, and leaving a crystalline globule, when it contains any phosphate of lead. The arsenate of lead is tender, friable, sometimes even pulverulent, and of specific gravity 5·04. That from the Saxon mines of Johann-Georgenstadt, consists, according to Rose, of oxide of lead, 77·5; arsenic acid, 12·5; phosphoric acid, 7·5; and chlorine, 1·5.

7. *Sulphide of lead. Galena* (*Bleiglanz*, Ger.).—This is the most abundant ore of lead; it may be indeed regarded as the only commercial ore of value, if we except the carbonates, which are probably formed by the decomposition of galena. Its prevailing forms are the cube and a combination of the cube and octahedron; lustre metallic, opaque, colour and streak *lead grey*. Fracture conchoidal, but difficult to obtain, owing to the readiness with which it cleaves. The localities of galena need not be named here, as the lead-producing districts, of which a list will be presently given, will include them, galena occurring in them all. Thomson's analysis of galena gives—

Lead	85·13
Sulphur	13·02
Iron	0·50

'It is a remarkable fact that silver should invariably be present in galena, sometimes, indeed, in very minute proportion; and the same generalisation may now be received as established with respect to the presence of gold. The silver, it is certain, usually exists in galena in the state of sulphide; and so, probably, does the gold. The mode of existence of sulphide of silver in galena is not always the same, as may be inferred from the fact that by *washing*, nearly the whole of the silver is carried away from some kinds of galena; while by the *same treatment* of other kinds of galena the loss of silver is inconsiderable. It is an error to suppose that largely-crystalline galena is generally poor in silver.'—*Percy.*

8. *Jamesonite* is a combination of lead, antimony, and sulphur. It occurs in acicular crystals, or in parallel or diverging groups, and more frequently in fibrous masses. It is found in many places in Cornwall and Devon. Rose's analysis gives the following as its composition:—

Lead	38·71
Antimony	34·90
Iron	2·96
Copper	0·21
Zinc	0·74
Sulphur	25·53
	103·05

Some *Jamesonite* found near Bampton in Devon contained 15 per cent. of silver.

9. *Bournonite* is found near Liskeard in Cornwall, not far from Kingsbridge, and close to Beer Alston in Devonshire. It occurs in many places on the Continent, and is found in both North and South America. Rammelsberg gives it the following composition:—

Lead	42·54
Antimony	24·71
Copper	13·03
Sulphur	19·72
	100·00

This mineral may be regarded as a double sulphide of lead and antimony, analogous to the double sulphide of copper and iron.

The following ores of lead are only of mineralogical interest:—

10. *Chloro-carbonate of lead. Cromfordite. Phosgenite. Horn-lead.*—This ore has a pale yellow colour, is reducible to metallic lead by the agency of soda, and is not altered by the hydrosulphides. Before the blowpipe it melts first into a pale yellow transparent globule, with salt of phosphorus and oxide of copper, and manifests the presence of chlorine. It is fragile, tender, softer than carbonate of lead, and is sometimes almost colourless, with an adamantine lustre. Spec. grav. 6·06. Its constituents, according to Berzelius, are, lead, 25·84; oxide of lead, 57·07; carbonate of lead, 6·25; chlorine, 8·84; silica, 1·46; water, 0·54, in 100 parts.

11. *Plattnerite. Super-* or *binoxide of lead.* A doubtful species.
12. *Linarite. Cupreous sulphate of lead.* Found at Leadhills, and in Cumberland.
13. *Susannite. Sulphato-carbonate of lead.* Occurs at Leadhills.
14. *Lanarkite. Sulphato-carbonate of lead.* Ditto.
15. *Leadhillite. Sulphato-tricarbonate of lead.* Ditto.
16. *Caledonite. Cupreous sulphato-carbonate of lead.* Ditto.
17. *Vanadinate. Vanadate of lead.*
18. *Wulfenite. Molybdate of lead.*
19. *Geocronite. Sulphantimonide of lead.*
20. *Mendipite. Oxychloride of lead.*
21. *Matlockite, ditto.*
22. *Crocoisite. Red lead ore* or *Chromate of lead.*
23. *Vauquelinite. Chromate of lead and copper.*

A few other lead-bearing minerals might have been named, but from their having no commercial value, it has not been thought necessary to do so.

The ores of lead, which may be represented by galena, or the sulphide of lead, that being the truly commercial variety, are found in rocks of different ages from the granite and clay-slates to the Triassic formations. In the Devonian slate rocks, in the neighbourhood of Liskeard in Cornwall are many most productive lead mines. To the north of Truro is the abandoned lead mine Huel Rose, which from its long celebrity gave its name to the district; and again to the south of Helstone there have been some valuable workings for lead. These formations of lead ore have all been in the clay-slate, or 'killas' rocks of Cornwall. In Devonshire many most valuable lead mines have been worked in similar rocks. In these the celebrated mines of Beer Alston on the Tamar existed. With a very few exceptions, but little lead has been discovered in the black slates,—the carboniferous series of Devonshire. Some lead ore has, however, been discovered in the New Red Sandstone and in the slate rocks immediately adjoining them near Newton St. Cyres. To the north of the carboniferous rocks of Devonshire we have a renewal of clay-slate rocks, similar in all respects to those which are found near Liskeard in Cornwall; in these rocks are the once famous argentiferous lead mines of Combe Martin, from which Edward the Black Prince derived an immense revenue.

The lead mines of the Mendip Hills, which were at one time very productive, are in the mountain-limestone formation. The lead which is now obtained from the Mendips is smelted from the refuse slimes and slags left by the old miners. Those of

Cardiganshire are found in clay-slates and gritstones, correspondent with or underlying the lowest beds described by Sir R. Murchison in his Silurian System.

In Shropshire we have lead ore occurring in the original Silurian rocks, the Llandeilo formation. 'In that lofty and rugged district of Shropshire which lies around the village of Shelve and the Corndon mountains, and which extends west of the Stiper Stones range into Montgomeryshire' (*Murchison*), lead lodes are abundant. In Derbyshire, in Yorkshire, in Cumberland, Northumberland, and Durham, the lead mines prove the most productive in the mountain-limestone formations, although there are some instances in which good lead mines have been worked in the sandstones and shales. In addition to these, we have the mines in the Leadhills and at Wanlockhead, consisting chiefly of the Silurian slates, in Scotland; Luganure, &c., in the granite districts of Wicklow, Newtonards in County Down, with a few others in Ireland, and the lead mines in the Silurian rocks of the Isle of Man,—these are the principal districts from which our large supplies of lead ore are obtained.

The principal lead mines at present worked in other parts of the world are the following:—1. Poullaouen and Huelgöet, near Carhair in France, department of Finisterre, being veins of galena, which traverse a clay-slate resting on granite. They have been known for upwards of three centuries; the workings penetrate to a depth of upwards of 300 yards, and in 1816, furnished 500 tons of lead per annum, out of which 1,034 pounds avoirdupois of silver were extracted. 2. At Villefort and Viallay, department of Lozère, are galena mines said to produce 100 tons of lead per annum, 400 kilogrammes of silver (880 lbs. avoird.). 3. At Pezey and Macot, to the east of Moutiers in Savoy, a galena mine exists in talc-schist, which has produced annually 200 tons of lead, and about 600 kilogrammes of silver (1,230 lbs. avoird.). 4. The mine of Vedrin near Namur in the Low Countries, is opened upon a vein of galena, traversing compact limestone of a transition district; it has furnished 200 tons of lead, from which 385 pounds avoirdupois of silver were extracted. 5. In Saxony the galena mines are so rich in silver as to make the lead almost overlooked. They are enumerated under Silver Ores. 6. The lead mines of the Hartz have been likewise considered as silver ones. 7. Those of Bleyberg in the Eifel are in the same predicament. 8. The galena mines of Bleyberg and Villach in Carinthia are in compact limestone. 9. In Bohemia to the south-west of Prague. 10. Mines of Joachimsthal and Bleistadt on the southern slope of the Erzgebirge, produce argentiferous galena. 11. There are numerous lead mines in Spain, the most important being in the granite hills of Linarès, upon the southern slope of the Sierra Morena, and in the district of the small town of Caujagar. Sometimes enormous masses of galena are extracted from the mines of Linarès. There are also mines of galena in Catalonia, Granada, Murcia, and Almeira, the ore of the last locality being generally poor in silver. 12. The lead mines of Sweden are very argentiferous, and worked chiefly with a view to the silver. 13. The lead mines of Daouria are numerous and rich, lying in a transition limestone, which rests on primitive rocks; their lead is neglected on account of the silver.

There have been a few lead mines in this country, which have been equally productive of silver. This was especially the case with the lead mine which was formerly worked near Combe Martin, and the mines formerly worked at Beer Alston in Devonshire. One of the most remarkable of recent examples, is a small mine known as Huel Florence, near Tavistock, from which some lead ore has been sold at upwards of 90*l.* a ton, on account of the large quantity of silver it contained. At the conclusion of this article some tables will be given, showing the argentiferous character of the different lead-producing districts of the United Kingdom.

Before proceeding to the consideration of the metallurgy of lead, a few brief notices of the history of lead mining may not be out of place.

As we have already stated, mining for lead must have been one of the earliest of man's subterranean labours, and at all periods of history we learn that lead mines have been worked. The Romans, especially, worked lead mines in Spain, and, after the conquest of this country, in many of our lead-producing districts, especially in Cardiganshire, Shropshire, and Flintshire.

Lead mining appears to have been carried on from a very early period in Alston Moor, and some other of the northern districts. But in the west of England, lead mining must be regarded as a somewhat recent industry.

Borlase mentions, in 1758, that lead mines had anciently and lately been worked in Cornwall, and that those most noted formerly were Penrose, Penwerty, Trevascus, Relestian, and Guarnek (Garras). He states that Penrose mines (near Helstone) had been wrought for about 200 years—that is, from about the middle of the sixteenth century—and that they had yielded tolerable profit within thirty years. The only lead mine worthy of note at work in his time, was at St. Issy, near Padstow. Pryce describes the lead ore of Garras, near Truro, to have been so argentiferous, that when wrought about 1720, it produced 100 oz. of silver in the ton of lead. Huel Pool, near Helstone, about 1790, yielded from 40 to 50 oz. of silver per ton of lead, and works were erected for extracting the silver. The lead ore of Wheal Rose contained 60 oz. of silver per ton.

In Devonshire, the Combe Martin and Beer Alston mines have long been celebrated for their argentiferous lead ores. It is stated that the produce of these mines was unusually great in the reigns of Edward I. and Edward II. In 1293, William de Wymundham accounted at the Treasury for 270 lbs. of silver raised in Devon. In 1294, it amounted to 521*l.* 10*s.* weight; and in 1294, to 704*l.* 3*s.* 1*d.* weight. In 1296, great profit is stated to have been derived from the Devon mines; and 360 miners were impressed out of Derbyshire and Wales to work in them. In 1360, a writ was issued, authorising certain persons to take up as many miners and workmen as should be necessary to work in the king's mines in Devon, allowing them reasonable wages according to the custom of the country; to arrest and imprison such as should resist, till they should give security to serve the king in the said mines, and to buy and provide timber at a competent price.

Henry, bishop of Winchester and cardinal of England, as one of the executors of John, duke of Bedford, who had a grant from the king of the gold and silver mines of Devon and Cornwall, rendered 26 lbs. and 2 oz. weight of pure silver as the 15th part of the pure silver raised in those counties from 15th December, 21st, to 16th August, 23rd of the same king's reign.

The Combe Martin mine was re-opened in the reign of Elizabeth. The working of this mine was strongly recommended to the Long Parliament in 1659; but Lysons observes that it does not appear to have been again worked until the close of that century, and then without success. In 1813 it was again opened and worked for four years, producing only 208 tons of ore in that time. In 1837 they were again worked, and it was evident that the previous mining operations had been very unskilfully managed. The two lodes near Beer Alston have produced large quantities of argentiferous galena, often containing from 80 to 120 oz. of silver per ton of lead. According to Mr. Hitchings, the greatest quantity which occurred in that part of them named the South Hooe mine was 140 oz. of silver per ton of lead. In 1784 and 1785 the silver produce of these mines amounted to 6,500 oz. From Huel Betsy, near Tavistock, which was re-opened in 1806, from 300 to 400 tons of lead, and from 4,000 to 5,000 oz. of silver, were annually obtained. Lead mines were worked at a very early period in the Isle of Man, but the recent workings only date from the commencement of the present century. The mines of Cardiganshire were evidently worked by the Romans. In the reigns of Henry VII. and of Elizabeth they attracted much attention, and German miners were invited to work them.

The English lead-miners distinguish three different kinds of deposits of lead ore: *rake-veins*, *pipe-veins*, and *flat-veins*. The English word 'vein' corresponds to the French term *filon*; but miners make use of it indifferently in England and France, to indicate all the deposits of this ore, adding an epithet to distinguish the different forms; thus, *rake-veins* are true veins in the geological acceptation of the word vein; *pipe-veins* are masses usually very narrow, and of oblong shape, most frequently parallel to the plane of the rocky strata; and *flat-veins* are small beds of ores interposed in the middle of these strata.

In the north of England, which, on account of its great preponderance in produce, we take as the basis of our description of lead mining, the ores are for the most part found in *veins* (*lodes* in Cornish) and flats. Although different names have been assigned to occasional varieties, the usual occurrence of lead ore is in rake-veins, or direct running veins, usually named as *veins*, with some distinctive appellation prefixed, as, for example, Rampgill Vein, Hudgillburn Vein. Other veins, lying parallel, receive a similar prefix, with the addition of the words north, east, or south; but for the last-named the word *sun* is often used; as, for instance, Hudgillburn Sun Vein, and 2nd and 3rd Sun Vein if further discoveries are made of other parallel veins. Considerable quantities of ore are also raised from horizontal extensions of portions of the vein called *flats*, and these are interposed between the strata adjacent to the vein.

Rake-veins are the most common form in which lead ore occurs in Cumberland. They are in general narrower in the sandstone which covers the limestone than in the calcareous beds. A thickness of less than a foot in the former becomes suddenly 3 or 4 feet in the latter; in the rich vein of Hudgillburn, the thickness is 17 feet in the *Great limestone*, while it does not exceed 3 feet in the overlying *Watersill* or sandstone. This influence exercised on the veins by the nature of the enclosing rock, is instructive; it determines at the same time almost uniformly their richness in lead ore, an observation similar to what has been made in other countries, especially in the veins of Kongsberg in Norway. The Cumberland veins are constantly richer, the more powerful they are, in the portions which traverse the calcareous rocks, than in the beds of sandstone, and more particularly the schistose rocks. It is rare in the rock called *plate* (a solid slaty clay) for the vein to include any ore; it is commonly filled with a species of potter's earth. The upper calcareous beds are also in general more productive than the lower ones. In most of these mines, the veins were not worked till lately below the fifth calcareous bed (the four-fathom limestone), which is 307 yards beneath the Millstone-Grit; and as the first limestone stratum is 108 yards beneath it, it follows that the thickness of the part of the ground where the veins are rich in lead does not in general exceed 200 yards. It appears, however, that veins have been mined in the neighbourhood of Alston Moor downwards to the eleventh calcareous stratum, or Tyne bottom limestone, which is 418 yards under the Millstone-Grit of the coal formation, immediately above the whinsill; and that they have been followed above the first limestone stratum, as high as the grindstone sill, which is only 83 yards below the same stratum of Millstone-Grit; so that in the total thickness of the plumbiferous formation is there more than 836 yards. It has been asserted that lead veins have been traced even further down, into the Memerby scar-limestone; but they have not been mined.

The greatest enrichment of a vein takes place commonly in the points where its two sides, being not far asunder, belong to the same rock; and its impoverishment occurs when one side is calcareous and the other a schistose clay. The minerals which most frequently accompany the galena are carbonate of lime, fluoride of calcium, sulphate of baryta, quartz, and pyrites.

The *pipe-veins* (*amas* in French) are seldom of great length; but some have a considerable width; their composition being somewhat similar to that of the rake-veins. They meet commonly in the neighbourhood of the two systems, sometimes being in evident communication together; they are occasionally barren; but when a wide pipe-vein is metalliferous, it is said to be very productive.

The *flat-veins*, or *strata-veins*, seem to be nothing else than expansions of the matter of the vein between the planes of the strata; and contain the same ores as the veins in their vicinity. When they are metalliferous, they are worked along with the adjacent rake-vein, and are productive to only a certain distance from that vein, unless they get enriched by crossing a rake-vein. Some examples have been adduced of advantageous workings in *flat-veins* in the *great limestone* of Cumberland, particularly in the mines of Coalcleugh and Nenthead. The *rake-veins*, however, furnish the greater part of the lead which Cumberland and the adjacent counties send every year into the market.

The metalliferous limestone occupies, in Derbyshire, a length of about 25 miles from north-west to south-east, under a very variable breadth, which towards the south amounts to 25 miles. Castleton to the north, Buxton to the north-west, and Matlock to the south-east, lie nearly upon its limits. It is surrounded on almost all sides by the Millstone-Grit, which covers it, and which is, in its turn, covered by the coal strata. The nature of the rocks beneath the limestone is not known. In Cumberland the metalliferous limestone includes a bed of trap, designated under the name of *whinsill*. In Derbyshire the trap is much more abundant, and it is thrice interposed between the limestone. These two rocks constitute of themselves the whole mineral mass, through a thickness of about 550 yards, measuring from the Millstone-Grit; only in the upper portion, that is near the Millstone-Grit, there is a pretty considerable thickness of argillo-calcareous schists.

Four great bodies or beds of limestone are distinguishable, which alternate with three masses of trap, called *toadstone*. The lead veins exist in the calcareous strata, but disappear at the limits of the toadstone. It has, however, been ascertained that they recur in the limestone underneath. See MINES and MINING.

METALLURGY OF LEAD.

Although lead forms an essential element in a large number of minerals, the ores of this metal are, strictly speaking, far from numerous. Of these the most important is sulphide of lead, or galena. This mineral, which possesses a metallic brilliancy, and has a lighter colour than metallic lead, presents, in its cleavage, all the variations from large facettes and laminæ indicating a cubic crystallisation to a most minutely granular structure. It is extremely brittle, and its powder presents a brilliant blackish-grey appearance.

The specific gravity of galena is 7·5 to 7·8, and its composition, when absolutely pure, is—

Lead	86·55
Sulphur	13·45
	100·00

The next most important ore of lead is the carbonate, which is a brittle mineral, of a white or greyish-white colour, having a specific gravity varying from 6·46 to 6·50. Its composition is—

Carbonic acid	16·05
Oxide of lead	83·56
	99·61

Large quantities of this substance occur in the mines of the Mississippi Valley in the United States of America, where they were formerly thrown away as useless, but have since been collected and smelted. Vast deposits of this substance have also been found in the Bunter sandstone, near Düren in Prussia, and at Freyung in Bavaria.

The extraction and mechanical preparation of ores is the business of the miner, and not of the metallurgist who receives them from the former freed as perfectly as possible from foreign matters.

The metallurgic processes, by the aid of which lead is obtained from galena, may be divided into two classes. The first of these is founded on the following reactions:—If one equivalent of sulphide of lead and two equivalents of the oxide of the same metal are fused together, the result is three equivalents of metallic lead and one equivalent of sulphurous acid, which is evolved.

This reaction is represented by the following equation:—

$$PbS + 2PbO = 3Pb + SO^2.$$

When, on the other hand, one equivalent of sulphide of lead and one equivalent of sulphate of lead are similarly treated, two equivalents of lead are obtained, and two equivalents of sulphurous acid are evolved. Thus:—

$$PbS + PbO,SO^3 = 2Pb + 2SO^2.$$

The process, founded on the foregoing reactions, and which we will distinguish as the *method by double decomposition*, consists in roasting the galena in a reverberatory furnace until a certain amount of oxide and sulphate has been formed, and subsequently, after having intimately mixed the charge, and closed the doors of the furnace causing the whole to enter into a state of fusion.

During this second stage of the operation, the reaction between the sulphides, sulphates, and oxides takes place, and metallic lead is eliminated. The roasting of the ore is, in some cases, conducted in the same furnace in which the fusion is effected, whilst in others two separate furnaces are employed.

The process by double decomposition is best adapted for the richer varieties of ore, and such as are least contaminated by siliceous or earthy impurities, and is consequently that which is almost universally employed for smelting the ores of this country.

By the second method, which we will call the *process by affinity*, the ore is fused with a mixture of metallic iron, which by combining with the sulphur liberates the metallic lead. This reaction will be understood by reference to the following equation:—

$$PbS + Fe = Pb + FeS.$$

In practice, however, metallic iron is not always employed for this purpose; cast iron is also frequently used, and in some instances the ores of iron and hammer-slags are substituted, as are also tap-cinder and other secondary products containing a considerable percentage of this metal. None of these substances are, however, found to be so efficacious as metallic iron, since cast iron requires to be decarburised before it can readily decompose the sulphide of lead; and the ores of iron require the introduction of various fluxes, and the consequent expenditure of an additional amount of fuel. In all cases, however, it is judicious to subject the ore to a preliminary roasting, in order to eliminate a portion of the sulphur, and thereby reduce the expenditure of iron, as well as to agglutinate the ore and render it better adapted for its subsequent treatment in the blast-furnace.

We will not attempt to describe the different forms given to roasting furnaces employed for the ores treated by this process, but would remark that they frequently resemble the kilns used for the preparation of lime, whilst in some instances the ores are roasted in heaps interstratified with wood or other fuel.

The method of treating ore by *affinity* is particularly adapted to those varieties that contain a considerable amount of silica, since such minerals, if treated by double decomposition, would, by the formation of oxide of lead, give rise to silicates, from which it would be exceedingly difficult to extract the metal.

English Process. Treatment by double decomposition.—Galena, if placed in a close vessel which protects it from the action of the air, and exposed to a gradually increasing temperature, becomes fused without the elimination of any lead taking place, but ultimately a portion of the sulphur is driven off, and a subsulphide is formed, which at a very elevated temperature is volatilised without change.

If, however, the vessel be uncovered, and the air allowed to act on its contents, oxygen combines with the sulphur, sulphurous acid is evolved, and the desulphuration of the mineral is slowly effected.

When galena is spread on the hearth of a reverberatory furnace, and is so placed as to present the largest possible amount of surface to oxidising influences, it will be found that the surface slowly becomes covered with a yellowish-white crust of sulphate of lead. The oxygen of the air, by combining with the two elementary bodies of which galena is composed, will evidently produce this effect. This is not, however, the only chemical change which takes place in the charge under these circumstances; oxide of lead is produced at the same time as the sulphate, or rather the formation of the oxide is prior to that of the sulphate.

In fact, during the first stage of the operation of roasting, sulphurous acid is evolved, the sulphur quits the lead, and a portion of that metal remains in a free state. This becomes oxidised by the air passing through the furnace, and subsequently a part of it combines with sulphuric acid, formed by the oxidation of sulphurous acid, and sulphate of lead is the result. In this way, after the expiration of a certain period, both oxide and sulphate of lead are present in the furnace.

During the early period of the roasting, when the temperature of the furnace is not very elevated, the proportion of sulphate is larger than that of the oxide formed, but in proportion as the heat of the apparatus increases, the production of oxide becomes more considerable, whilst that of the sulphate diminishes.

The sulphate and oxide thus formed re-act in their turn on the undecomposed galena, whilst a portion of the latter, by combining with the sulphide of lead, gives rise to the formation of oxysulphide.

This last compound has no action on galena, except to dissolve it in certain proportions, but is readily decomposed by the aid of carbonaceous matter.

It is therefore evident that the addition of carbon, at this stage of the operation, will have the effect of reducing the oxide and oxysulphide of lead.

Every process then that has for its object the reduction of lead ores by double decomposition, comprises two principal operations: 1st. The reduction of galena, by the aid of heat and atmospheric air, to a mixture of sulphide, oxide, and sulphate, which mutually decompose each other, with the elimination of metallic lead; 2nd. The reduction of the oxysulphide by the addition of carbonaceous matter.

The Reverberatory Furnace.—The reverberatory furnace employed for the treatment of galena is composed, like all other furnaces of this description, of three distinct parts,—the fire-place, the hearth, and the chimney.

The hearth has to a certain extent the form of a funnel, of which the lowest point is on the front side of the furnace immediately below the middle door. The molten metal, descending from every side along the inclined bottom or sole, is collected in this receptacle, and is ultimately run off by means of a proper tap-hole. This tap-hole is, during the operation, closed by a pellet of clay.

The inclination of the hearth is more rapid in the vicinity of the fire-bridge than towards the chimney, in order that the liquid metal may not be too long exposed to the oxidising and volatilising influences of a current of strongly-heated air.

The dimensions given to these furnaces, as well as the weight of the charge operated on at one time, vary considerably in different localities, but in the north of England the following measurements are usually employed:—The fire-grate is 5 feet 9 inches × 1 foot 10 inches, and the thickness of the fire-bridge 1 foot 6 inches; the length of the sole is 9 feet, and its average width 7 feet. The depth of the tap is about 2 feet 6 inches below the top of the inclined sole. The height of the roof at the fire-end may be 1 foot 4 inches, and at the other extremity 11 inches.

The introduction of the charge is in some cases effected by the doors of the furnace, whilst in other instances a hopper, placed over the centre of the arch, is made use of.

On the two sides of the furnace are placed three doors, about 11 inches × 9 inches, which are distinguished as 1, 2 and 3, counting from the fire-bridge end. The three doors on the one side are known as the front doors, whilst those on the other side are called the back doors. Immediately beneath the door on the front side of the furnace is situated the iron pan into which the molten lead is tapped off.

The bottom of this arrangement is in most cases composed of fire-bricks, covered by a layer of vitrified slags, of greater or less thickness. In order to form this bottom, the slags are introduced into the furnace, the doors closed, and the damper raised. An elevated temperature is thus quickly obtained, and as soon as the scoriæ have become sufficiently fused, they are, by means of rakes and paddles, made to assume the required form. The charge employed, as before stated, varies in almost every establishment. In the North, however, smaller charges are used than in most other localities. At Newcastle, and in the neighbourhood, the charge varies from 12 to 14 cwts.; in Wales, and near Bristol, 21-cwt. charges are treated; whilst in Cornwall, charges of 30 cwts. are not unfrequently worked. The time required for smelting a charge varies with its weight and the nature of the ores, from 6 to 24 hours.

In some cases the ore is introduced raw into the furnace, whilst in others it undergoes a preliminary roasting previous to its introduction. Rich ores are generally smelted without being first calcined; but the poorer varieties, and particularly those which contain large quantities of iron pyrites, are, in most instances, subjected to roasting in a separate furnace.

In order to understand more clearly the operation of smelting in furnaces of this description, we will suppose that a charge has just been tapped off, and that, after thoroughly clearing the hearth, a fresh charge of raw ores has been introduced. During the first part of the operation of roasting, which usually occupies about two hours, the doors are taken off to admit free access of air, and also for the purpose of cooling the furnace, which has been strongly heated at the close of the preceding operation. No fuel is at this period charged upon the grate, since the heat of the furnace is of itself sufficient to effect the elimination of the first portions of sulphur. The ore is carefully stirred, for the purpose of constantly presenting a fresh surface to oxidising influences, and when white fumes are no longer observed to pass off in large quantities, a little coal may be thrown on the grate, and the temperature gradually elevated until the charge becomes slightly clammy and adheres to the rake. When the roasting is considered as being sufficiently advanced, the smelter turns his attention to the state of the fire, taking care to remove the clinkers and get the grate into proper condition for the reception of a fresh supply of fuel. The furnace doors are now closed, and a strong heat is kept up for about a quarter of an hour, when the smelter examines the condition of his charge by removing one of the doors. If the operation is progressing satisfactorily, and the lead flowing freely and passing without obstruction into the tap, the firing is continued a little longer; but when the ores have been found to have taken fire, or are lying unevenly on the bottom of the furnace, the position of the charge is changed by the use of an iron paddle. During this operation the furnace becomes partially cooled, and the reduction of temperature thus obtained is frequently found to produce decompositions, which facilitate the reduction of the charge. In the case of extremely refractory ores, this alternate heating and cooling of the furnace is sometimes almost indispensable, whilst, in other instances, their being once or twice raked over is all the manipulation that is required.

We will suppose that four hours have now elapsed since the charging of the furnace, and that the charge has run down the inclined sole towards the tap. The smelter now examines the condition of the scoriæ, and adds a couple of shovelfuls of lime and three or four shovelfuls of small coals, the amount and relative proportions of these being regulated in accordance with the aspect of the slags. The charge is now, by means of proper tools, again raised to the breast of the furnace, and the firing continued until the charge has run down into the tap-hole. The foreman now takes his rake and feels if any lumps remain in an unfused condition, and if he finds all to be in a fluid state he calls his assistant from the other side, and by the addition of a small quantity of lime and fine coal, makes the slag assume a pasty or rather doughy consistency. By the aid of his paddle he now pushes this compound up to the opposite side of the furnace, where it is drawn by an assistant through the back door into a trough containing water. Whilst the assistant is doing this, the foreman is busily engaged in tapping off the metal into the iron pan in front of the furnace, from which, when sufficiently cooled, it is laded out into suitable moulds.

The total duration of the operation may be about six hours.

To build a furnace of the above description, 5,000 common bricks, 2,000 fire-bricks, and 2½ tons of fire-clay are required. In addition to this, must be reckoned the iron-work, the expense of which will be much influenced by the nature of the armatures employed and the locality in which the furnace is constructed.

The amount of fuel employed for the treatment of a ton of lead ore varies not only in relation to the richness of the mineral, but is also much influenced by the nature of the associated matrix and the calorific value of the fuel itself. The loss of metal experienced during the operation is mainly dependent on the richness of the ore treated and the skill and attention of the foreman.

In the North about 12 cwts. of coal are consumed in the elaboration of 1 ton of ore, and the loss of metal on 60 per cent. ore may be estimated at about 12 per cent., of which about 6½ per cent. is subsequently recovered from the slag and fumes. At a well-conducted smelting works, situated in the west of England, in which the average assay of the ores smelted during the year was 75½, the yield from the smelting furnaces was 68½ per cent., and the coal used per ton of ore was 13¾ cwts. The lead recovered from the slag and fumes amounted to 2¾ per cent., making the total yield of metal 71¼ per cent., and the loss on the assay produce 4½ per cent.

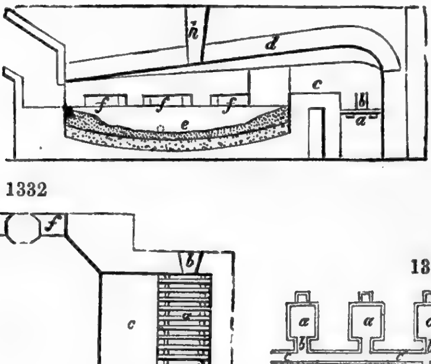
In this establishment the men are paid from 7*s*. 6*d*. to 12*s*. 6*d*. per ton of lead, in accordance with the nature of the ores operated on.

In one establishment the process before described is somewhat varied. The charge employed is 21 cwts. This is run down and tapped off at the expiration of 6 hours, and about 9 pigs of 1¼ cwt. each usually obtained. A second charge of 21 cwts. is then dropped in, and, as soon as it is roasted, mixed with the slags of the former operation. The whole is then run down in the ordinary way, the slags drawn and the lead tapped off in 9 hours. The produce of the second or double charge is from 14 to 15 pigs.

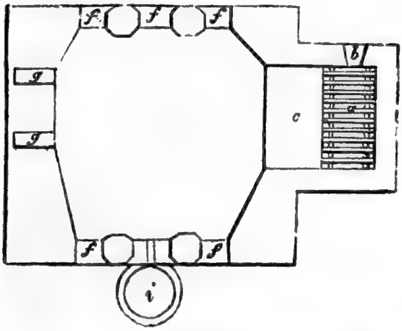
If the ores are difficult to flow, 16 to 16½ hours are required for the two charges. A small quantity of black slag from the slag hearth is employed for drying up.

Figs. 1331, 1332, 1333, represent the reverberatory furnace at the Marquis of Westminster's lead-smelting works, two miles from Holywell. The hearth is hollowed out below the middle door of the furnace; it slopes from the back and ends towards this basin. The distance from the lowest point of this concavity up to the sill of the door, is usually 24 inches, but it is sometimes a little less, according to the quality of the ores to be smelted. This surface has no hole for running off the slag, above the level of the tap-hole for the lead, like the smelting furnace of Lea, near Matlock. A single chimney stack serves for all the establishment; and receives all the flues of the various roasting and reducing furnaces. *Fig.* 1333 gives an idea of the distribution of these flues. *a a a*, &c., are the furnaces; *b*, the flues, 18 inches square; these lead from each furnace to the principal conduit *c*, which is 5 feet deep by 2½ wide; *d* is 6 feet deep by 3 wide; *e* is a round chamber, 15 feet in diameter; *f* is a conduit, 7 feet high by 5 wide; *g* another, 6 feet high by 3 wide. The chimney at *h* has a diameter at bottom of 30 feet, at top of 12 feet, including the thickness of its sides, forming a truncated cone 100 feet high; whose base stands upon a hill a little way from the furnaces, and 62 feet above their level.

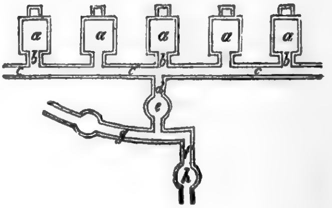
1331



1332



1333



a, *figs*, 1331, 1332, is the grate; *b*, the door of the fire-place; *c*, the fire-bridge; *d*, the arched roof; *e*, the hearth; *f f f*, &c., the working doors; *g g*, flues running into one conduit, which leads to the subterranean condensing-chamber *e*, and thence to the general chimney; *h*, a hopper-shaped opening in the top of the furnace, for supplying it with ores.

This magnificent structure is not destined solely for the reduction of the ores, but also for dissipating all the vapours which might prove noxious to the health of the work-people and to vegetation

The ores smelted at Holywell are very refractory galenas, mixed with blende, calamine, pyrites, carbonate of lime, &c., but without any fluoride of calcium. They serve mutually as fluxes to one another. The coal is of inferior quality. The sole of each furnace is formed of slags obtained in the smelting, and they are all of one kind. In constructing it, 7 or 8 tons of these slags are first thrown upon the brick area of the hearth; are made to melt by a brisk fire, and in their stiffening state, as they cool, they permit the bottom to be sloped and hollowed into the desired shape. Four workmen, two at each side of the furnace perform this task.

The ordinary charge of ore for one smelting operation is 20 cwts., and it is introduced through the hopper. An assistant placed at the back doors spreads it equally over the whole hearth with a rake; the furnace being meanwhile heated only with the declining fire of a preceding operation. No regular fire is made during the first two hours, but a gentle heat merely is kept up by throwing one or two shovelfuls of small coal upon the grate from time to time. All the doors are closed, and the register-plate of the chimney lowered.

The outer basin in front of the furnace is at this time filled with the lead derived from a former process, the metal being covered with slags. A rectangular slit above the tap-hole is left open, and remains so during the whole time of the operation, unless the lead should rise in the interior basin above the level of that orifice; in which case a little mound must be raised before it.

The two doors in front furthest from the fire being soon opened, the head-smelter throws in through them, upon the sole of the furnace, the slags swimming upon the bath of lead, and a little while afterwards he opens the tap-hole, and runs off the metallic lead reduced from these slags. At the same time his assistant turns over the ore with his paddle, through the back doors. These being again closed, while the above two front doors are open, the smelter throws a shovelful of small coal or coke cinder upon the lead-bath, and works the whole together, turning over the ore with the paddle or iron oar. About three quarters of an hour after the commencement of the operation, he throws back upon the sole of the hearth the fresh slags which then float upon the bath of the outer basin, and which are mixed with coaly matter. He next turns over these slags, as well as the ore with the paddle, and shuts all the doors. At this time the smelter lades off the lead into the pig-moulds.

The assistant now turns over the ore once more through the back doors. A little more than an hour after the operation began, a quantity of lead proceeding from the slag last remelted is run off by the tap; being usually in such quantity as to fill one half of the outer basin. Both the workmen then turn over the ore, with the paddles, at the several doors of the furnace. Its interior is at this time of a dull red heat; the roasting being carried on rather by the combustion of the sulphurous ingredients, than by the action of the small quantity of coal in the grate. The smelter, after shutting the front doors, with the exception of that next the fire-bridge, lifts off the fresh slags lying upon the surface of the outside bath, drains them, and throws them back into the furnace.

An hour and a half after the commencement, the lead begins to ooze out in small quantities from the ore; but little should be suffered to flow before two hours have expired. About this time the two workmen open all the doors, and turn over the ore, each at his own side of the furnace. An hour and three quarters after the beginning, there are few vapours in the furnace, its temperature being very moderate. No more lead is then seen to flow upon the sloping hearth. A little coal being thrown into the grate to raise the heat slightly, the workmen turn over the ore, and then close all the doors.

At the end of two hours, the *first fire* or roasting being completed, and the doors shut, the register is to be lifted a little, and coal thrown upon the grate to give the *second fire*, which lasts during 25 minutes. When the doors are now opened, the inside of the furnace is of a vivid red colour, and the lead flows down from every side towards the inner basin. The smelter with his rake or paddle pushes the slags upon that basin back towards the upper part of the sole, and his assistant spreads them uniformly over the surface through the back doors. The smelter next throws in by his middle door, a few shovelfuls of quicklime upon the lead-bath. The assistant meanwhile for a quarter of an hour works the ore and the slags together through the three back doors, and then spreads them out, while the smelter pushes the slags from the surface of the inner basin back to the upper part of the sole. The doors being now left open for a little, while the interior remains in repose, the metallic lead, which had been pushed back with the slags, flows down into the basin. This occasional *cooling* of the furnace is thought to be necessary for the better separation of the products, especially of the slags from the red bath.

In a short time the workmen resume their rakes, and turn over the slags along with the ore. Three hours after the commencement a little more fuel is put into the grate, merely to keep up a moderate heat of the furnace during the paddling. After three hours and ten minutes, the grate being charged with fuel for the *third fire*, the register is completely opened, the doors are all shut, and the furnace is left in this state for three quarters of an hour. In nearly four hours from the commencement, all the doors being opened, the assistant levels the surfaces with his rake, in order to favour the descent of any drops of lead; and then spreads the slags, which are pushed back towards him by the smelter. The latter now throws in a fresh quantity of lime, with the view not merely of covering the lead-bath and preventing its oxidation, but of rendering the slags less fluid.

Ten minutes after the third fire is completed, the smelter puts a new charge of fuel on the grate, and shuts the doors of the furnace to give it the *fourth fire*. In four hours and forty minutes from the commencement, this fire being finished, the doors are opened, the smelter pierces the tap-hole to discharge the lead into the outer basin, and throws some quicklime upon the slags in the inner basin. He then pushes the slags thus *dried up* towards the upper part of the hearth, and his assistant rakes them out by the back doors.

The whole operation of a *smelting shift* takes about four hours and a half, or at most five hours, in which four periods may be distinguished:—

1. The *first fire* for roasting the ores requires very moderate firing, and lasts two hours.

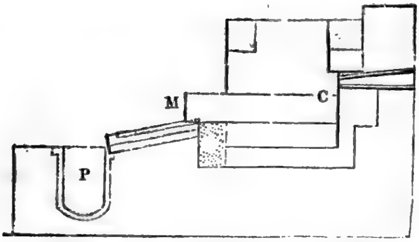
2. The *second fire*, or smelting, requires a higher heat, with shut doors; at the end the slags are *dried up* with lime, and the furnace is also allowed to cool a little.

3, 4. The last two periods, or the *third* and *fourth fires*, are likewise two smeltings or foundings, and differ from the first only in requiring a higher temperature. The heat is greatest in the last. The form and dimensions of the furnace are calculated to cause a uniform distribution of heat over the whole surface of the hearth. Sometimes billets of green wood are plunged into the metallic lead of the outer basin, causing an ebullition which favours the separation of the slags, and consequently the production of a purer lead; but no more metallic metal is obtained.

Ten cwts. of coal are consumed at Holywell in smelting one ton of the lead-ore *schlich* or sludge; but at Grassington, near Skipton in Yorkshire, with a similar furnace worked with a slower heat, the operation taking from seven hours to seven hours and a half, instead of five, only 7½ cwts. of coal are consumed. But here the ores are less refractory, have the benefit of fluor-spar as a flux, and are more exhausted of their metal, being smelted upon a less sloping hearth.

The ore-hearth.—This furnace, called by the French *fourneau écossais*, is from 22 to 24 inches in height and 1 foot by 1½ in area inside; but its horizontal section, always rectangular, varies much in its dimensions at different levels, as shown in *fig.* 1334.

1334



C, Tuyère. M, Workstone. P, Lead-pot.

Treatment of lead ores by the Scotch furnace or ore-hearth.—This furnace is generally employed in the counties of Northumberland, Cumberland, and Durham for the smelting of lead ores, which were formerly carried to them without any preparation, but they are now often exposed to a preliminary calcination. The roasted ore yields in the Scotch furnace a more considerable product than the crude ore, because it forms in the furnace a more porous mass, and at the same time *it works drier*, to use the founder's expression; that is, it allows the stream of air impelled by the blast to diffuse itself more completely across the matters contained in the furnace.

In proceeding to smelt by means of an ore-hearth, two workmen are required to be in attendance from the beginning to the end of each smelting shift, the duration of which is from 12 to 15 hours. The first step in commencing a smelting shift is to fill up the hearth-bottom, and space below the workstone with *peats*, placing one already kindled before the nozzle of the bellows. The powerful blast very soon sets the whole in a blaze, and by the addition of small quantities of coal at intervals, a body of fire is obtained, filling the hearth. Roasted ore is now put upon the surface of the fire, between the forestone and pipestone, which immediately becomes heated red hot and reduced; the lead from it sinking down and collecting in the hearth bottom. Other portions of ore of 10 or 12 lbs. each are introduced from time to time, and the contents of the hearth are stirred and kept open, being occasionally drawn out and examined upon the workstone, until the hearth bottom becomes full of lead. The hearth may now be considered in its regular working state, having a mass of heated fuel, mixed with partly-fused and semi-reduced ore, called *Brouze*, floating upon a stratum of melted lead. The smelting shift is then regularly proceeded with by the two workmen, as follows:—The fire being made up, a stratum of ore is spread upon the horizontal surface of the *brouze*, and the whole suffered to remain exposed to the blast for the space of about five minutes. At the end of that time, one man plunges a poker into the fluid lead, in the hearth bottom below the *brouze*, and raises the whole up, at different places, so as to loosen and open the brouze, and in doing so, to pull a part of it forwards upon the workstone, allowing the recently-added ore to sink down into the body of the hearth. The poker is now exchanged for a shovel, with a head 6 inches square, with which the brouze is examined upon the workstone, and any lumps that may have been too much fused, broken to pieces; those which are so far agglutinated by the heat, as to be quite hard, and further known by their brightness, being picked out, and thrown aside, to be afterwards smelted in the slag hearth. They are called 'grey slags.' A little slaked lime, in powder, is then spread upon the brouze, which has been drawn forward upon the workstone, if it exhibit a pasty appearance; and a portion of coal is added to the hearth, if necessary, which the workman knows by experience. In the mean time, his fellow workman, or shoulder fellow, clears the opening, through which the blast passes into the hearth, with a shovel, and places a peat immediately above it, which he holds in its proper situation, until it is fixed, by the return of all the brouze, from the workstone into the hearth. The fire is made up again into the shape before described, a stratum of fresh ore spread upon the part, and the operation of stirring, breaking the lumps upon the workstone, and picking out the hard slags repeated, after the expiration of a few minutes, exactly in the same manner. At every stirring a fresh peat is put above the nozzle of the bellows, which divides the blast, and causes it to be distributed all over the hearth; and as it burns away into light ashes, an opening is left for the blast to issue freely into the body of the brouze. The soft and porous nature of dried peat renders it very suitable for this purpose; but, in some instances, where a deficiency of peats has occurred, blocks of wood of the same size have been used with little disadvantage. As the smelting proceeds, the reduced lead, filtering down through all parts of the brouze into the hearth bottom, flows through the channel, out of which it is laded into a proper mould, and formed into pigs.

The principal particulars to be attended to in managing an ore-hearth properly during the smelting shift are these: First.—It is very important to employ a proper blast, which should be carefully regulated, so as to be neither too weak nor too powerful. Too weak a blast would not excite the requisite heat to reduce the ore, and one too powerful has the effect of fusing the contents of the hearth into slags. In this particular no certain rules can be given; for the same blast is not suitable for every variety of ore. Soft free-grained galena, of great specific gravity, being very fusible, and easily reduced, requires a moderate blast; while the harder and lighter varieties, many of which contain more or less iron, and are often found rich in silver, require a blast considerably stronger. In all cases, it is most essential, that the blast should be no more than sufficient to reduce the ore, after every other necessary precaution is taken in working the hearth. Second.—The blast should be as much divided as possible, and made to pass through every part of the brouze. Third.—The hearth should be vigorously stirred, at due intervals, and part of its contents exposed upon the workstone; when the partially-fused lumps should be well broken to pieces, as well as those which are further vitrified, so as to form slags, carefully picked out. This breaking to pieces, and exposure of the hottest part of the brouze upon the workstone, has a most beneficial effect in promoting its reduction into lead; for the atmospheric air immediately acts upon it, and, in that heated state, the sulphur is readily consumed, or converted into sulphurous acid, leaving the lead in its metallic state; hence it is that the reduced lead always flows most abundantly out of the hearth immediately after the return of the brouze, which has been spread out and exposed to the atmosphere. Fourth.—The quantity of lime used should be no more than is just necessary to thicken the brouze sufficiently; as it does not in the least contribute to reduce the ore by any chemical effect: its use is merely to render the brouze less pasty, if, from the heat being too great, or from the nature of the ore, it has a disposition to become very soft. Fifth.—Coal should also be supplied judiciously; too much unnecessarily increasing the bulk of the brouze, and causing the hearth to get too full.

When the ore is of a description to smelt readily, and the hearth is well managed in every particular, it works with but a small quantity of brouze, which feels dry when stirred, and is easily kept open and permeable to the blast. The reduction proceeds rapidly with a moderate degree of heat, and the slags produced are inconsiderable; but, if in this state, the stirring of the brouze and exposure upon the workstone are discontinued, or practised at longer intervals, the hearth quickly gets too hot, and immediately begins to agglutinate together; rendering evident the necessity of these operations to the successful management of the process. It is not difficult to understand why these effects take place, when it is considered, that in smelting by means of the ore-hearth, it is the oxygen of the blast and of the atmosphere which principally accomplishes the reduction; and the point to be chiefly attended to consists in exposing the ore to its action, at the proper temperature, and under the most favourable circumstances. The importance of having the ores free from impurities is also evident; for the stony or earthy matter it contains impedes the smelting process, and increases the quantity of slags. A very slight difference of composition of perfectly-dressed ore may readily be understood to affect its reducibility; and hence it is, that ore from different veins, or the same vein in different strata, as before observed, is frequently found to work very differently when smelted singly in the hearth. It happens, therefore, that with the best workmen, some varieties of ore require more coal and lime, and a greater degree of heat than others; and it is for this reason that the forestone is made moveable, so as to answer for ore which works either with a large or a small quantity of brouze.

It has been stated that the duration of a smelting shift is from 12 to 15 hours, at the end of which time, with every precaution, the hearth is apt to become too hot, and it is necessary to stop for some time, in order that it may cool. At mills where the smelting shift is 12 hours, the hearths usually go on 12 hours, and are suspended 5; four and a half or five bings[1] of ore (36 to 40 cwts.) are smelted during a shift, and the two men who manage the hearth work each four shifts per week; terminating their week's work at 3 o'clock on Wednesday afternoon. They are succeeded by two other workmen, who also work four 12-hour shifts; the last of which they finish at 4 o'clock on Saturday. In these eight shifts, from 36 to 40 bings of ore are smelted, which, when of good quality, produce from 9 to 10 fodders[2] of lead. At other mills where the shift is 14 or 15 hours, the furnace is kindled at 4 o'clock in the morning, and worked until 6 or 7 in the evening each day, six days in the week; during this shift 5 or 5½ bings of ore are smelted, and two men at one hearth, in the early part of each week, work three such shifts, producing about 4 fodders of lead—two other men work each three shifts in the latter part of the week, making the total quantity smelted per week, in one hearth, from 30 to 33 bings.

Hearth-ends and Smelter's fume.—In the operation of smelting, as already described, it happens that particles of unreduced and semi-reduced ore are continually expelled from the hearth, partly by the force of the blast, but principally by the decrepitation of the ore on the application of heat. This ore is mixed with a portion of the fuel and lime made use of in smelting, all of which are deposited upon the top of the smelting-hearth, and are called hearth-ends. It is customary to remove the hearth-ends from time to time, and deposit them in a convenient place until the end of the year, or some shorter period, when they are washed to get rid of the earthy matter they may contain, and the metallic portion is roasted at a strong heat, until it begins to soften and cohere into lumps, and afterwards smelted in the ore-hearth, exactly in the same way as ore undergoing that operation for the first time, as already described.

It is difficult to state what quantity of hearth-ends are produced by the smelting of a given quantity of ore, but in one instance the hearth-ends produced in smelting 9,751 bings, on being roasted and reduced in the ore-hearth, yielded of common lead 315 cwts., and the grey slags separated in this process gave, by treatment in the slag-hearth, 47 cwts. of slag-lead; making the total quantity of lead 362 cwts., which is at the rate of 3 cwts. 2 qrs. 23 lbs. from the smelting of 100 bings of ore.

Slag-hearth.—The various slags obtained from the different operations of lead smelting are divided into two classes. Those which do not contain a sufficient amount of metal to pay for further treatment are thrown away as useless, whilst those in which the percentage of lead is sufficiently large are treated by the slag-hearth.

Figs. 1335, 1336, represent a slag-hearth, the *fourneau à manche* (elbow furnace) of the French, and the *Krummofen* (crooked furnace) of the Germans; such as is used at Alston Moor, in Cumberland, for the reduction of the lead-slag. It resembles the Scotch furnace. The shaft is a parallelopiped, whose base is 26 inches by 24 inches in area inside, and whose height is 3 feet; the sole-plate *a*, of cast iron, slopes slightly down to the basin of reception, or the fore-hearth, *b*. Upon both of the long sides of the sole-plate there are cast-iron beams, called *bearers*, *c*, *c*, of great strength, which support the side walls built of a coarse-grained sandstone, as well as the cast-iron plate *d* (*forestone*), which forms the front of the shaft. This stands 7 inches off from the sole-plate, leaving an empty space between them. The back side is made of cast iron, from the sole-plate to the horizontal tuyère in its middle; but above this point it is made of sandstone. The tuyère is from 1½ to 2 inches in diameter. In front of the fore-hearth *b*, a cistern, *e*, is placed, through which water continually flows, so that the slags which spontaneously overflow the fore-hearth may become inflated and divided, whereby the lead disseminated through them may be readily separated by washing. The lead itself flows from the fore-hearth *b*, through an orifice into an iron pot, *f*, which is kept over a fire. The metal obtained from this slag-hearth is much less pure than that extracted directly from the ore.

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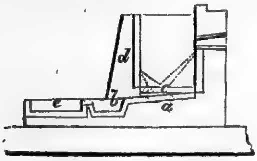
[1] 1 bing=8 cwts.

[2] 1 fodder=21 cwts.

1335



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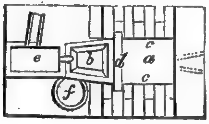
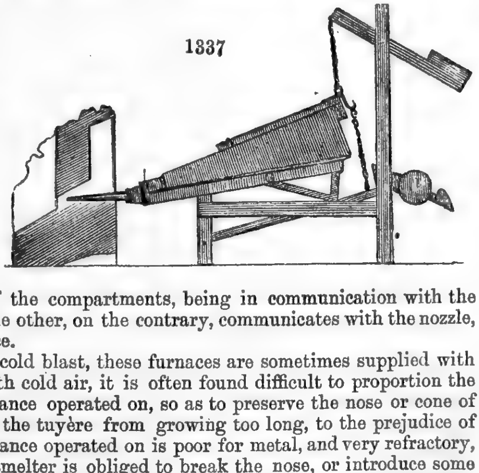


The whole bottom of the furnace is filled to a height of 17 inches, that is, to within 2 or 3 inches of the tuyère, with the rubbish of coke reduced to coarse powder and beat strongly down. At each *smelting shift*, this bed must be made anew, and the interior of the furnace above the tuyère repaired, with the exception of the front, consisting of cast iron. In advance of the furnace there is a basin of reception, which is also filled with coke rubbish. Farther off is the pit, full of water, replenished by a cold stream, which incessantly runs in through a pipe. The scoriæ, in flowing out of the furnace, pass over the coke bed in the basin of reception, and then fall into the water, whose coolness makes them fly into small pieces, after which they are easily washed, so as to separate the lead that may be entangled among them.

These furnaces are urged sometimes by fans or by wooden bellows, *fig.* 1337. But at the smelting works of Lea, near Matlock, the blowing-machine consists of two casks, which move upon horizontal axes. Each of these casks is divided into two equal parts by a fixed plane that passes through its axis, and is filled with water to a certain height. The water of one side communicates with that of the other by an opening in the lower part of the division. Each cask possesses a movement of oscillation, produced by a rod attached to a crank of a bucket-wheel. At each demi-oscillation one of the compartments, being in communication with the external air, is filled; whilst the other, on the contrary, communicates with the nozzle, and supplies wind to the furnace.

1337



Instead of being blown by a cold blast, these furnaces are sometimes supplied with heated air. When smelting with cold air, it is often found difficult to proportion the quantity of slag or other substance operated on, so as to preserve the nose or cone of slag which forms at the end of the tuyère from growing too long, to the prejudice of the operation. When the substance operated on is poor for metal, and very refractory, it frequently happens that the smelter is obliged to break the nose, or introduce some very fusible substance in order to melt it off. By the introduction of hot air this inconvenience is removed, since by increasing or lowering the temperature of the blast, the nose may be allowed to lengthen or shorten, according as the nature of the slags may require. The temperature found to answer best is from 250° to 300° Fahr.; since when it is heated to from 500° to 600°, it is found impossible to form a nose of sufficient length to convey the blast to the front of the hearth, and therefore the back, which is expensive to rebuild, is quickly destroyed.

The advantage to be derived from the use of the hot blast will be evident, from the result of two experiments which were tried some years since:—

Twenty-eight tons of slag smelted with cold blast consumed 392 cubic feet of air per minute.

Labour cost	£3	7	8
Coke, 7 tons, at 24*s.* 6*d.*	8	11	6
Total	£11	19	2

Thirty-five tons of similar slag smelted with hot blast consumed 300 cubic feet of air per minute.

	£	s.	d.
Labour cost	£3	7	8
Coke, 5 tons, 17 cwts., at 24*s.* 6*d.*	7	3	4
Turf for heating air, 11 loads, 1*s.* 8*d.*	0	18	4
Total .	£11	9	4

From which it will be seen that, with one-quarter part less air, a quarter part more slag was melted per week, and a saving of expense of nearly 10*s.* effected.

The loss of lead experienced in smelting by the slag-hearth is, however, very great, even under the most favourable circumstances; and it has, consequently, of later years been gradually superseded by the Castilian furnace, which will be shortly described. Many large and well-conducted establishments still however continue to employ the slag-hearth, and when well constructed and skilfully managed, the loss arising from volatilisation may be considerably reduced.

Castilian Furnace.—Within the last few years a blast-furnace has been introduced into the lead-works of this country which possesses great advantages over every other description of apparatus which has been hitherto employed for the treatment of lead ores of low produce. This apparatus, although first employed in Spain, was invented by an Englishman (Mr. W. Goundry) who was employed in the reduction of rich slags in the neighbourhood of Carthagena.

This furnace is circular, usually about 2 feet 4 inches, or 2 feet 6 inches in diameter, and is constructed of the best fire-bricks, so moulded as to fit together, and allow all the joints to follow the radii of the circle described by the brick-work. Its usual height is 8 feet 6 inches, and the thickness of the masonry invariably 9 inches. In this arrangement the breast is formed by a semicircular plate of cast iron, furnished with a lip for running off the slag, and has a longitudinal slot, in which is placed the tapping-hole.

On the top of this cylinder of brick-work a box-shaped covering of masonry is supported by a cast-iron framing, resting on four pillars, and in this is placed the door for feeding the furnace, and the outlet by which the various products of combustion escape to the flues. The lower part of this hood is fitted closely to the body of the furnace, whilst its top is closed by an arch of 4½-inch brick-work laid in fire-clay. The bottom is composed of a mixture of coke-dust and fire-clay, slightly moistened, and well beaten to the height of the top of the breast-pan, which stands nearly 3 feet above the level of the floor. Above the breast-pan is an arch so turned as to form a sort of niche, 18 inches in width, and rather more than 2 feet in height.

When the bottom has been solidly beaten, up to the required height, it is hollowed out so as to form an internal cavity, communicating freely with the breast-pan, which is filled with the same material, and subsequently hollowed out to a depth slightly below the level of the internal cavity. The blast is supplied by three water tuyères, 3 inches in diameter at the smaller end, 5½ inches at the larger, and 10 inches in length. Into these the nozzles are introduced, by which a current of air is supplied by means of a fan or ventilator making about 800 revolutions per minute. The blast may be conveniently conducted to the nozzles through brick channels formed beneath the floor of the smelting-house.

The ores treated in this furnace ought never to contain more than 30 per cent. of metal, and when richer, must be reduced to about this tenure by the addition of slags and other fluxes. In charging this apparatus, the coke and ore are supplied stratum super stratum, and care must be taken so to dispose the coke as not to heat too violently the brickwork of the furnaces. In order to allow the slags which are produced to escape freely into the breast-pan, a brick is left out of the front of the furnace at the height of the fore-hearth, which, for the purpose of preventing the cooling of the scoriæ, is kept covered by a layer of coke-dust or cinders. From the breast-pan the slags flow constantly off over a spout into cast-iron waggons, where they consolidate into masses, having the form of truncated pyramids, of which the larger base is about 2 feet square. As soon as a sufficient amount of lead is accumulated in the bottom of the furnace, it is let off into a lateral lead-pot, by removing the clay-stopper of the tap-hole situated in the slot of the breast-pan, and, after being properly skimmed, it is laded into moulds. When, in addition to lead, the ore treated likewise contains a certain portion of copper, this metal will be found in the form of a matt floating on the surface of the leaden bath. This, when sufficiently solidified, is removed, and, after being roasted, is operated on for the copper it contains.

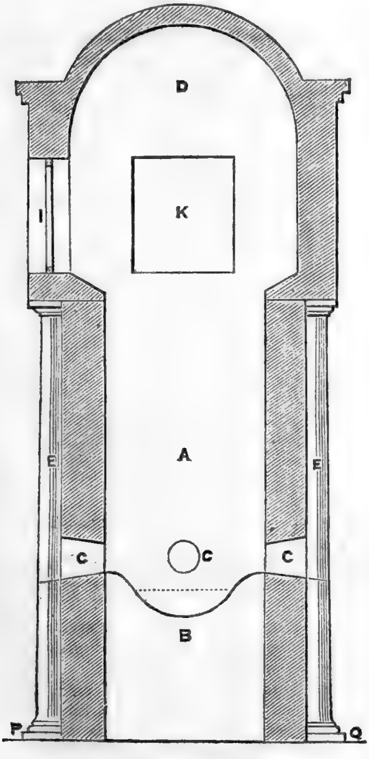
The waggons in which the liquid slag runs off are frequently made to traverse small railways, by which, when one mass has been removed, its place may readily be supplied by an empty waggon. When nearly cold, the casings of the waggons are turned over, and the blocks of slag easily made to drop out. In addition to the facility for transport obtained in this way, one of the great advantages obtained by this method of manipulation arises from the circumstance that should the furnaces at any time run lead or matt, without its being detected by the smelter, the whole of it will be collected at the bottom of the block, from which, when cold, it may be readily detached.

In working these furnaces care must be taken to prevent flame from appearing at the tunnel-head, since, provided the slags are sufficiently liquid, the cooler the apparatus is kept the less will be the loss of metal through volatilisation. In addition to the greatest attention being paid to the working of the furnace, it is necessary, in order to obtain the best results, that all establishments in which this apparatus is employed should be provided with long and capacious flues, in which the condensation of the fumes takes place, previous to arriving at the chimney-shaft. These flues should be built at least 3 feet in width, and 6 feet in height, so as readily to admit of being cleaned, and are often made of several thousand yards in length. The value of the fumes so condensed, amounts to many hundreds, and in some instances thousands per annum.

In order to be advantageously worked in these furnaces, the ores should be first roasted, and subsequently agglomerated into masses, which, after being broken into fragments of about the size of the fist, and mixed with the various fluxes, are charged as before described.

In an establishment in which the average assay produce of the roasted ore for lead is 42$\frac{4}{5}$ths, the furnace yield is 38$\frac{13}{14}$ths, and the weight of coke employed to effect the reduction 22 per cent. of the roasted ore operated on. The mixture charged into the furnace, in this instance, is composed of 100 parts of roasted ore, 42 parts of slags from a previous operation, 8 parts of scrap iron, and 7 parts of limestone. Each

1338



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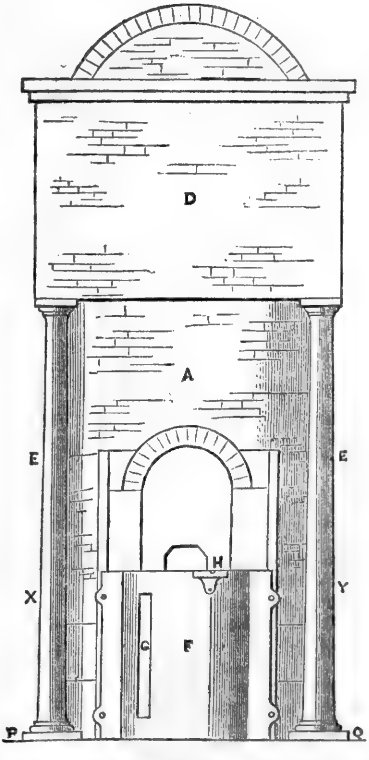
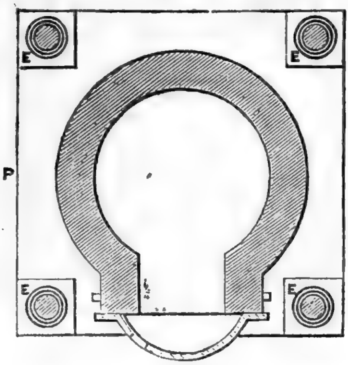


furnace works off about seven tons of roasted ore in the course of 24 hours; the weight of slags run off is about double that of the lead obtained, and the matt removed from the surface of the pan is nearly 5 per cent. of the lead produced. The ores treated in this establishment consist of galena, much mixed with spathose iron, and are therefore somewhat refractory. A furnace of this kind requires for its construction about 1,000 segmental fire-bricks, and the same number of ordinary fire-bricks of second quality.

Figs. 1338, 1339, 1340, and 1341 represent respectively a vertical section, an elevation, a ground plan, and an horizontal section of a Castilian furnace. The section *fig.* 1341 is on the line X Y, *fig.* 1339. A is the body of the furnace, B, the bottom, composed of a mixture of coke-dust and fire-clay; C C C, the tuyères; D, the rectangular covering of masonry; E E E E, cast-iron pillars; F, the breast-pan; G, slot for tapping hole; H, lip of breast-pan; I, feeding-door; K, flue-hole; P, Q, ground line.

1340



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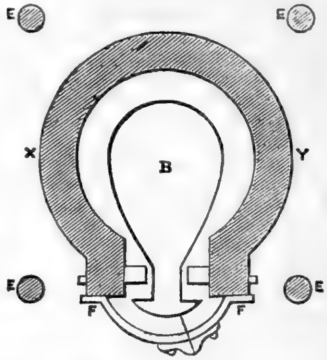

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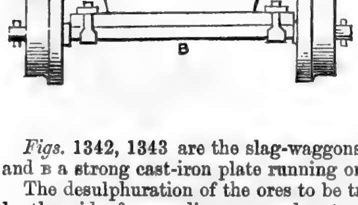

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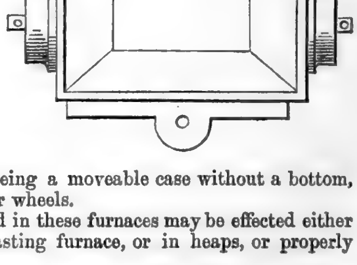


Figs. 1342, 1343 are the slag-waggons, A being a moveable case without a bottom, and B a strong cast-iron plate running on four wheels.

The desulphuration of the ores to be treated in these furnaces may be effected either by the aid of an ordinary reverberatory roasting furnace, or in heaps, or properly constructed kilns.

The kilns best adapted for this purpose consist of rectangular chambers, having an arched roof, and provided with proper flues for the escape of the evolved gases, as well as a wide door for charging and withdrawing the ore to be operated on.

Each of these chambers is capable of containing from 25 to 30 tons of ore; and, in order to charge it, a layer of faggots and split wood is laid on the floor, and this, after having been covered by a layer of ore about two feet in thickness, is ignited, care being at the same time taken to close, by means of loose brick-work, the opening of the door to the same height. When this first layer has become sufficiently ignited, a fresh stratum of ore, mixed with a little coal or charcoal, is thrown upon it, and when this layer has in its turn become sufficiently heated, more ore is thrown on. In this way ore is from time to time added, until the kiln has become full, when the orifice of the doorway is closed by an iron plate, and the operation proceeds regularly and without further trouble until the greater portion has become eliminated.

This usually happens at the expiration of about four weeks from the time of first ignition, and the brick-work front is then removed, and the ores broken out, and after being mixed with proper fluxes, passed through the blast-furnace.

The proportion of wood necessary for the roasting of a ton of ore by this means must necessarily depend on the composition of the minerals operated on; but with ores of the description above-mentioned, and in a neighbourhood where wood is moderately cheap, the desulphuration may be effected at a cost of about 5*s.* per ton.

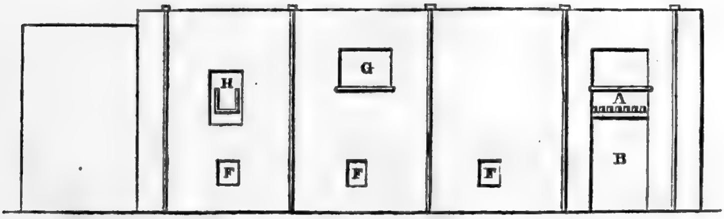
Calcining.—The lead obtained by the various processes above described generally contains a sufficient amount of silver to render its extraction of much importance; but, in addition to this, it is not unfrequently associated with antimony, tin, copper, and various other impurities, which require to be removed before the separation of the silver can be effected.

This operation consists in fusing the hard lead in a reverberatory furnace of peculiar construction, and allowing it to remain, when in a melted state, exposed to the oxidising influences of the gases passing through the apparatus. By this treatment the antimony, copper, and other impurities become oxidised, and on rising to the surface of the metallic bath are skimmed off, and removed with an iron rake. The hearth of the furnace in which this operation is conducted consists of a large cast-iron pan, which may be 10 feet in length, 5 feet 6 inches in width, and 10 inches in depth. The fire-place, which is 1 foot 8 inches in width, has a length equal to the width of the pan, and is separated from it by a fire-bridge 2 feet in width. The height of the arch at the bridge-end is 1 foot 4 inches above the edge of the pan, whilst at the outer extremity it is only about 8 inches.

The lead to be introduced into the pan is first fused in a large iron pot fixed in brick-work at the side of the furnace, and subsequently laded into it through an iron gutter adapted for that purpose. The length of time necessary for the purification of hard lead obviously depends on the nature and amount of the impurities which it contains; and, consequently, some varieties will be sufficiently improved at the expiration of twelve hours, whilst in other instances it is necessary to continue the operation during three or four weeks. The charge of hard lead varies from eight to eleven tons.

When the metal is thought to be in a fit state for tapping, a small portion taken out with a ladle, and poured into a mould used for this purpose, is found on cooling to assume at the surface a peculiar crystalline appearance, which when once seen is readily again recognised. As soon as this appearance presents itself, an iron plug is withdrawn from the bottom of the pan, and the lead run off into an iron pan, from which it is subsequently laded into moulds.

1344



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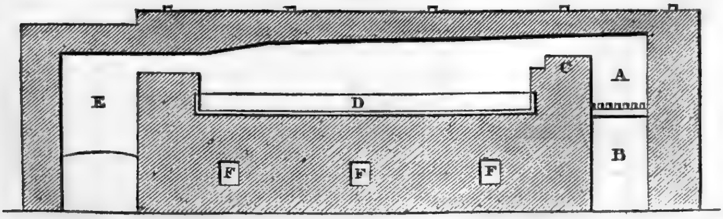
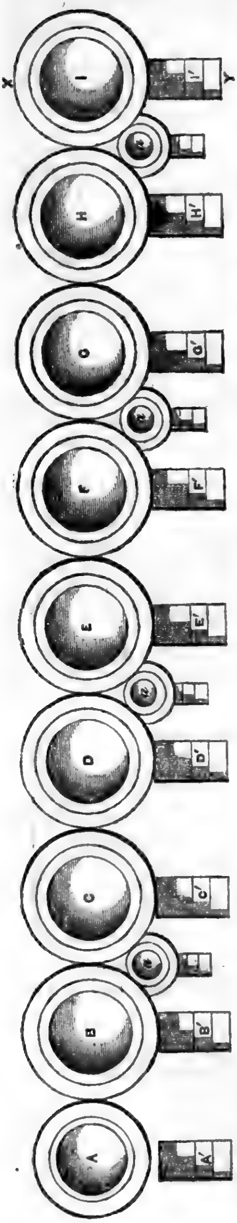
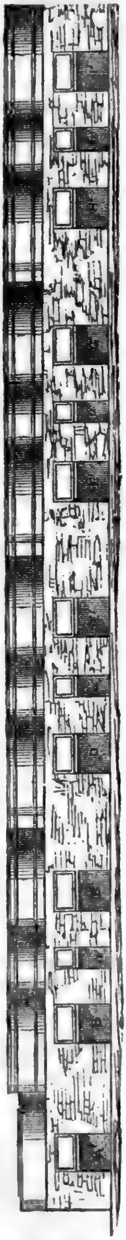


The construction of a furnace of this description requires 5,000 common bricks, 3,500 fire-bricks, and 2 tons of fire-clay.

1347

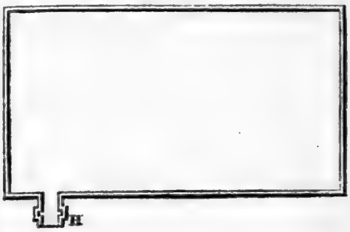


1348



Figs. 1344 and 1345 represent an elevation and vertical section of the calcining furnace. **A** is the fire-place; **B**, ash-pit; **C**, fire-bridge; **D**, cast-iron pan; **E**, flue; **F F F**, channels for allowing the escape of moisture; **G**, one of the working doors; **H**, spout for running off calcined metal. *Fig.* 1346 represents the pan removed from the masonry, and shows a groove in the lip for the introduction of a sheet-iron dam, tightened with moistened bone-ash for keeping in the fused metal.

1346



In the more modern furnaces of this description, the corners are usually rounded to prevent breakage from expansion, whilst the tapping is effected by means of a hole through the bottom near one of the sides. This, when closed, is stopped by means of an iron plug kept in its place by a weighted lever.

Concentration of the silver.—This process is founded on the circumstance, first noticed in the year 1829, by the late H. L. Pattinson, of Newcastle-on-Tyne, that when lead containing silver is melted in a suitable vessel, afterwards slowly allowed to cool, and at the same time kept constantly stirred, at a certain temperature near the melting point of lead, metallic crystals begin to form. These, as rapidly as they are produced, sink to the bottom, and on being removed are found to contain much less silver than the lead originally operated on. The still fluid portion, from which the crystals have been removed, will at the same time be proportionally enriched.

This operation is conducted in a series of 8 or 10 cast-iron pots, set in a row, with fire-places beneath. These are each capable of containing about 6 tons of calcined lead, and, on commencing an operation, that quantity of metal, containing, we will suppose, 20 oz. of silver per ton, is introduced into a pot (say **F**, *fig.* 1347) about the centre of the series. This, when melted, is carefully skimmed with a perforated ladle, and the fire immediately withdrawn. The cooling of the metal is also frequently hastened by throwing water upon its surface, and whilst cooling it is kept constantly agitated by means of a long iron stirrer or slice. Crystals soon begin to make their appearance, and these as they accumulate and fall to the bottom are removed by means of a large perforated ladle, in which they are well shaken, and afterwards carried over to the next pot to the left of the workman. This operation goes on continually until about 4 tons of crystals have been taken out of the pot F, and have been placed in pot E, at which time the pot F may contain about 40 oz. of silver to the ton, whilst that in E will only yield 10 oz. The rich lead in F is then laded into the next pot G, to the right of the workman, and the operation repeated in F, on a fresh quantity of calcined lead.

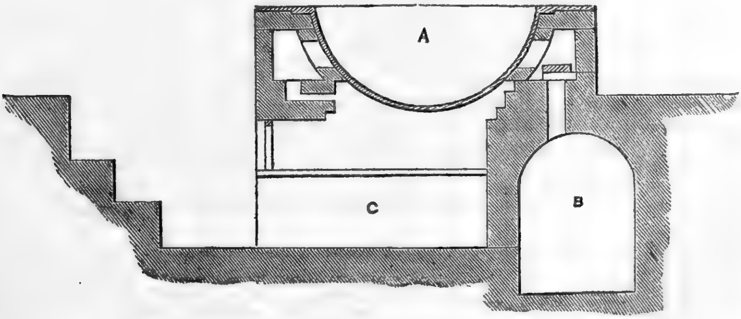
In this way calcined lead is constantly introduced, and the resulting poor lead passes continually to the left of the workman, whilst the rich is passing towards his right. Each pot in succession, when filled with lead of its proper produce for silver, is in its turn crystallised, the poor lead passing to the left of the workman, and the enriched lead to his right. By this method of treatment it is evident that the crystals obtained from the pots to the left of the workman must gradually be deprived of their silver, whilst the rich lead passing to his right becomes continually richer. The final result is, that at one end of the series the poor lead contains very little silver, whilst at the other an exceedingly rich alloy of lead and silver is obtained.

The poor lead obtained by this process should never contain more than 12 dwts. of silver per ton, whilst the rich lead is frequently concentrated to 500 oz. to the ton. This rich lead is subsequently cupelled in the refining furnace.

The ladle employed for the removal of the crystals, when manual labour is made use of, is about 16 inches in diameter, and 5 inches in depth, but when cranes are used, much larger ladles are easily managed. A form of crane has been invented which effects considerable economy of labour in this operation. When, during the operation of crystallisation, the ladle becomes chilled, it is dipped into a small vessel containing lead of a higher temperature than that which is being worked, and known by the name of a temper-pot. The pot containing the rich lead is generally called the No. 1 pot; in some establishments, however, the last pot in which the poor lead is crystallised obtains this appellation.

Figs. 1347 and 1348 represent a plan and elevation of a set of Pattinson's pots, arranged in the most approved way. A is the 'market pot,' from which the desilverised lead is laded out. B, C, D, E, F, G, H, and I, are the working pots, whilst A′, B′, C′, D′, E′, F′, G′, H′, and I′, are their respective fire-places. The 'temper pots,' *a a a a*, are employed for heating the ladles when they have become too much reduced in temperature.

1349



The *figs.* 1349 and 1350 are sections showing the manner of setting and the arrangement of the pots and flues. A, pot; B, main flue; C, ash-pit.

The erection of nine six-ton pots requires 15,000 common bricks, 10,000 fire-bricks, 160 feet of quarles, 80 fire-clay blocks, and 5 tons of fire-clay.

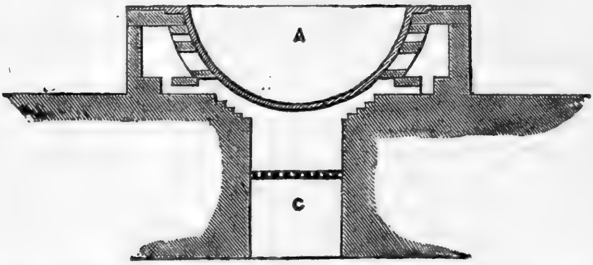
In some establishments ten-ton pots are employed, and where cranes are made use of they are found to be advantageous.

Refining.—The extraction of the silver contained in the rich lead is conducted in a cupel forming the bottom of a reverberatory furnace called a refinery.

In this operation the litharge produced, instead of being absorbed by the substance of the cupel, is run off in a fluid state, by means of a depression called a gate.

The size of the fire-place varies with the other dimensions of the furnace, but is usually nearly square, and in an apparatus of ordinary size may be about 2 feet × 2 feet 6 inches. This is separated from the body of the furnace by a fire-bridge 18 inches in breadth, so that the flame and heated air pass directly over the surface of the cupel, and from thence escape by means of two separate apertures into the main flues of the establishment. The cupel or test consists of an oval iron ring, about 5 inches in depth, its greatest diameter being 4 feet, and its lesser nearly 3 feet. This frame, in order to better support the bottom of the cupel, is provided with cross-bars about 4½ inches wide and ½ inch in thickness. In order to make a test, this frame is beaten full of finely-powdered bone-ash, slightly moistened with water, containing a small quantity of pearlash in solution, which has the property of giving consistency to the cupel when heated.

1350



The centre of the test, after the ring has been well-filled with this mixture, and solidly beaten down, is scooped out with a small trowel, until the sides are left 2 inches in thickness at top, and three inches at the bottom, whilst the thickness of the sole itself is about 1 inch.

At the fore part or wide end of the test the thickness of the border is increased to 6 inches, and a hole is then cut through the bottom, which communicates with the openings or gates by which the fluid litharge makes its escape.

The test, when thus prepared, is placed in the refinery furnace, of which it forms the bottom, and is wedged to its proper height against an iron ring firmly built into the masonry. When this furnace is first lighted, it is necessary to apply the heat very gradually, since if the test were too strongly heated before it became perfectly dry, it would be liable to crack. As soon as the test has become thoroughly dry, it is heated to incipient redness, and is nearly filled with the rich lead to be operated on, which has been previously fused in an iron pot at the side of the furnace, and beneath which is a small grate where a fire is lighted.

The melted lead, when first introduced into the furnace, becomes covered with a greyish dross, but on further increasing the heat, the surface of the bath uncovers, and ordinary litharge begins to make its appearance.

The blast is now turned on, and forces the litharge from the back of the test up to the breast, where it passes over the gate, and falls through the aperture between the bone-ash and the ring into a small cast-iron pot running on wheels. The air, which is supplied by a small ventilator, not only sweeps the litharge from the surface of the lead towards the breast, but also supplies the oxygen necessary for its formation.

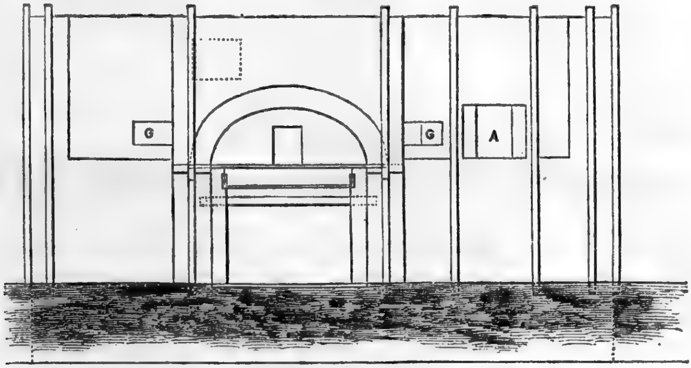
In proportion as the surface of the lead becomes depressed by its constant oxidation, and the continual removal of the resulting litharge, more metal is added from the melting pot, so as to raise it to its former level, and in this manner the operation is continued until the lead in the bottom of the test has become so enriched as to render it necessary that it should be tapped. The contents of the test are now so far reduced in volume that the whole of the silver contained in the rich lead operated on remains in combination with a few hundred-weights only of metal, and this is removed by carefully drilling a hole in the bone-ash forming the bottom of the test. The reason for the removal of the rich lead, is to prevent too large an amount of silver from being carried off in the litharge, which is found to be the case when lead containing a very large amount of that metal is operated on.

When the rich lead has been thus removed, the tapping hole is again closed by a pellet of bone-ash, and another charge immediately introduced.

As soon as the whole of the rich lead has been subjected to cupellation, and has become thus further enriched, the argentiferous alloy is itself similarly treated, either in a fresh test, or in that employed for the concentration of the rich lead. The brightening of pure silver at the moment of the separation of the last traces of lead, indicates the precise period at which the operation should be terminated, and the blast is then turned off, and the fire removed from the grate. The silver is now allowed to set, and as soon as it has become hardened, the wedges are removed from beneath the test, which is placed on the floor of the establishment. When cold, the silver plate is detached from the test, and any adhering particles of bone-ash removed by the aid of a wire-brush.

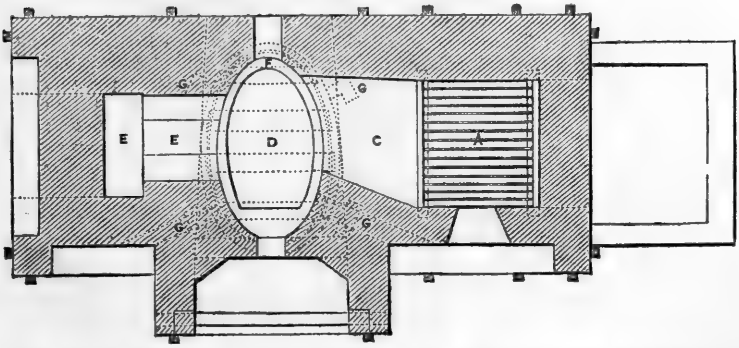
A test furnace of ordinary dimensions requires for its construction about 2,000 common bricks, 2,000 fire-bricks, and 1½ ton of fire-clay. A furnace of this kind will work off 4 pigs of lead per hour, and consume 4 cwts. of coal per ton of rich lead operated on.

1351



Figs. 1351, 1352, and 1353, represent an elevation, plan, and section of a refining furnace; A, fire-place; B, ash-pit; C, fire-bridge; D, test-ring, shown in its proper position; E, flues; F, point where blast enters; G, pig-holes.[1]

1352



The cost of working a ton of rich lead in the neighbourhood of Newcastle, containing on an average 400 oz. of silver per ton, is as follows:—

	s.	d.
Refiner's wages	4	2·1
Coals, 4 cwts.	0	6·8
Engine wages	1	7·0
Coals, 5 cwts.	0	8·7
Pearlash	0	3·5
Bone-ash, 17·3 lbs.	3	1·0
Repairs	0	5·0
Total	10	10·1

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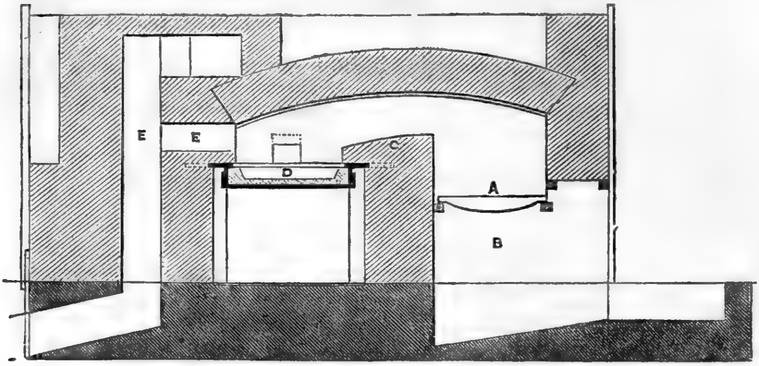
[1] Pig-holes are used for introducing the lead in cases in which it is not laded into the test in a fused state.

Parkes' Process of Desilverising Lead by Zinc.—When lead and zinc are melted together and allowed to cool slowly, an almost complete separation occurs, the zinc, owing to its lower specific gravity and higher melting-point, cools first and may be removed in a solid crust, while the lead is still liquid underneath. Mr. Alexander Parkes of Birmingham, found that argentiferous lead might be freed from its silver by melting with it zinc; and in the process of cooling the zinc crystallises and takes out the silver; the silver may afterwards be removed from the zinc by dissolving in hydrochloric or in dilute sulphuric acid, and the zinc may be used again and again for melting with the lead. Mr. Parkes first patented his process in 1850; he improved it in 1851; and in 1852, he was granted a third patent, entitled 'Improvements in separating Silver from other Metals.' The process is as follows: There are two vessels over separate fires, one a Pattinson pot of cast iron, which will hold 7 tons of molten metal—this is for the lead—and a smaller one for melting the charge of zinc. When the 7 tons of lead to be desilverised is melted, it is skimmed, the temperature is raised to that of molten zinc, and the charge of zinc (about 1 cwt. to every ton of lead, or $1\frac{3}{4}$ lb. to every ounce of silver) which has been previously melted is laded into the lead, and the whole well stirred with a perforated rabble to insure perfect intermixture; the mass is then left to gradually cool. When the surface has hardened, it is skimmed off with a perforated ladle, and the surface of the liquid lead is skimmed off as well. The lead thus treated contains about 10 dwts. of silver per ton. The solidified zinc is placed in a retort, which is oval on bore, and placed a little on the incline over a fire for the purpose of liquation; it is heated above the melting point of lead, but decidedly below that of zinc, and so the lead that is taken up with the zinc drains off at the lower end of the retort into an iron pot placed convenient to it. The zinc, which has been thus drained of the lead, but still contains the silver, is distilled in a Belgian retort with twice its bulk of lime and its own bulk of coal; the zinc, being much more volatile than the silver, is distilled over, and the residue is very rich in silver. The partially-desilverised lead is submitted to a softening process for the separation of any remaining zinc. It is kept melted at a good red heat for a period of from 9 to 12 hours, during which time it is skimmed twice, first, after the first three hours, and again half an hour before tapping. The lead is tapped into a cast-iron receiver, and therein subjected to 'boiling;' that is, green wood is kept submerged in it, held down by a lever. Lead treated in this manner is said to contain a small quantity of silver, but no zinc.

1353



These processes were supposed to have been improved by Flach, who patented his processes in this country in 1866. Although Flach's process has been used, it is said, with success on the Continent, it has never been permanently adopted in this country.

The difficulty with Parkes' process has been the separation of the zinc from the desilverised lead. A process for effecting this was patented by Cordurié of Toulouse in 1866. Lead to be desilverised was treated by him in the usual manner with zinc. After the removal of the crust of argentiferous zinc, superheated steam is passed into the desilverised lead, whereby the zinc retained by the lead is oxidised by the oxygen of the steam; this oxide rises to the surface in the state of powder, and is skimmed off. According to Gruner, who wrote on his process in the *Annales des Mines*, the result at Rothschild's works at Havre was most satisfactory. The desilverised zinciferous lead contained 0·75 per cent. of zinc; but after it had been subjected to the action of steam, it yielded only the most feeble traces of zinc.

A process for the desilverisation of lead by zinc has been described by E. Koch in the *Berg- und Huetten-maennische Zeitung.* In order to make the process continuous the author liquates his lead from copper in a reverberatory furnace with an inclined hearth. The liquated lead is received in a Pattinson kettle, which when it contains a charge is emptied by a siphon-tap into a lower kettle. In the second kettle the antimony is oxidised by steam, and the lead then siphoned into the lower kettles, where it is desilverised by zinc, the latter being fastened in front of the lower mouth of the siphons, so as to bring it into intimate contact with the lead. The desilverised lead is then siphoned into a still lower kettle, where the zinc is removed by steam, and then siphoned into a still lower kettle, whence it is siphoned into iron moulds. The advantages claimed for this method of plant are, a more perfect utilisation of heat, greater production of metals before the addition of zinc (*i.e.*, copper and antimony), saving in the amount of zinc, less wear of kettles, and a more suitable shape of these last.

Decopperisation of Lead by Zinc.—Mr. W. Baker of Sheffield has successfully carried out this process. When a certain portion of zinc is melted with lead containing copper, a zinc alloy with a small portion of lead is formed, and most of the copper is withdrawn from the lead with it, which floats on the surface in a pasty mass, and may be skimmed off.

In operating upon 100 tons of lead containing from 10 to 15 oz. of copper to the ton, the copper was reduced on the average to 1 oz. and 21 grs. per ton.

Mr. Baker thus describes the operation: Five tons of lead are melted, skimmed, and kept sufficiently hot to prevent the metal setting at the sides of the pot. 28 lbs. of zinc are melted with about 2 cwts. of lead in a small pot adjacent. This pot already contains about 14 lbs. of zinc, together with some lead from a previous operation. When quite liquid more lead is added from the larger pot, in order to dilute the alloy before mixing with the entire charge. The contents of the small pot, which should be not enough to prevent any alloy separating, are then added to the charge and stirred well into the melted metal. The fire is now withdrawn, and the whole allowed to cool down. In a short time a pasty alloy rises to the surface and is removed by a perforated skimmer into the small pot. This operation is continued until the lead begins to set at the sides of the pan. The charge must then be re-heated, and the alloy in the small pot liquated by heating at a regulated temperature, which will permit of the zinc alloy being removed from a quantity of zinciferous lead, which will be left with only a trace of copper. 14 lbs. more zinc are now melted with this residue in the small pot, and the operation is repeated. More certain results are obtained by thus adding the zinc in two portions. Finally, all the zinc dross and alloy are liquated in the small pot. The quantity of alloy obtained is about 1 cwt. This will contain about 25 per cent. of zinc, or 28 lbs. of the zinc employed for one operation. It may be estimated that 14 lbs. will be left in the decopperised lead, and 14 lbs. also in the liquated product remaining in the small pot ready for the next operation. The zinc remaining in the decopperised lead is oxidised in a reverberatory furnace with a slag bottom, or in a pan such as is used in the furnaces for softening hard lead. In a round pan containing from 8 to 10 tons, set in a furnace of the latter description, a charge was worked off in about 30 hours, including charging and tapping out. From 90 tons an average of 95 per cent. of softened lead was obtained. The dross was easily reduced, and yielded ordinary soft lead.

The zinc alloy containing copper and also most of the silver is best economised by melting down in a small blast-furnace, when a rich argentiferous lead may be obtained.

Natro-Metallurgy.—The various processes of refining lead employed at the present day causes, in cases where the metal is impure, considerable waste, and necessitate the reduction of an enormous quantity of oxide, to which they are, besides, inadequate for the removal of certain foreign metals. A new plan, which has recently been devised by MM. Pagen and Rous of Marseilles, France, allows the complete refining of any argentiferous lead without the formation of oxides of lead, and has, according to the *Chronique de l'Industrie*, the particular advantage of permitting the collection of all foreign metals, of which the value may be worth considering. The process is founded on the property which a bath of caustic, hydrated, melted alkali possesses in dissolving, or at least oxidising, successively, all the metals except three, by drawing them into a soluble scoria, in a state of igneous fusion. The three exceptions are lead, silver, and gold. The metals united with the lead are, one after the other, removed by melted soda, the action of the bath being maintained, first by a jet of steam, designed to restore constantly the water of the hydrate from which the metals gain oxygen, and urged according as the metals are in a less degree oxidisable, either by a blast of air, or finally, by carefully measured additions of nitrate of soda. The theory of the reaction is as follows: By simple solution in water, soda abandons all the oxides which it holds in solution or suspension, and is evaporated and dried for use, in the operation, almost without loss. The metals oxidise in the melted alkaline bath in the order of their affinity for oxygen, an order modified, however—(1) by their particular affinity for soda; (2) by the action of affinity exercised by the largest mass present. Thus, tin and the metals of platinum, although much less oxidisable than lead or copper, are attacked very rapidly; and before the latter in the soda-bath, by reason of their propensity to act as electro-negative elements. Hence, also, in an alloy very rich in lead the copper oxidises first. Another phenomenon of not less importance is that the solutions of the oxides in the soda-bath act chemically in presence of the re-agents exactly as do the metallic salts dissolved in water. It is thus in this igneous solution—all the metals are precipitated one after the other, in the inverse order of their solubility, and in the direct order they preserve each other from oxidation. In this respect even insoluble reducing agents, such as charcoal, may be employed in the bath. The principal applications in the process are its adaptation, not only to the refining of lead and the extraction of silver by the zinc process from lead and argentiferous scoriæ, but the purification of argentiferous copper and old complex alloys; the treatment of ores of platinum, gold, silver, &c., of ores of chromium, &c. Since March last the inventors have constructed a plant, and have carried on the process at Marseilles; and we learn that the hard leads of Greece (containing 2½ per cent. antimony, 1 per cent. arsenic, ½ per cent. copper, and 1 to 2 per cent. iron and sulphur), hard Spanish lead, and other forms of the metal containing large quantities of foreign substances, have been successfully treated. A company has been formed for the fusion of ores, separation of metals, and then refining by the process of natro-metallurgy.

Reducing.—The reduction to the metallic state of the litharge from the refinery, the pot-dross, and the mixed metallic oxides from the calcining furnace, is effected in a reverberatory apparatus, somewhat resembling a smelting furnace, except that its dimensions are smaller, and the sole, instead of being lowest immediately below the middle door, gradually slopes from the fire-bridge to near the flue, where there is a depression in which is inserted an iron gutter, which constantly remains open, and from which the reduced metal flows continuously into an iron pot placed by the side of the furnace for its reception, whence it is subsequently laded into moulds.

The litharge, or pot-dross, is intimately mixed with a quantity of small coal, and is charged on that part of the hearth immediately before the fire-bridge. To prevent the fused oxide from attacking the bottom of the furnace, and also to provide a sort of hollow filter for the liquid metal, the sole is covered by a layer of bituminous coal.

The heat of the furnace quickly causes the ignition of this stratum, which is rapidly reduced to the state of a spongy cinder. The reducing gases present in the furnace, aided by the coal mixed with the charge itself, cause the reduction of the oxide, which, assuming the metallic form, flows through the interstices of the cinder, and ultimately finding its way into the depression at the extremity of the hearth, flows through the iron gutter into the external cast-iron pot. The surface of the charge is frequently, during the process of elaboration, turned over with an iron rake, for the double purpose of exposing new surfaces to the action of the furnace, and also to allow the reduced lead to flow off more readily.

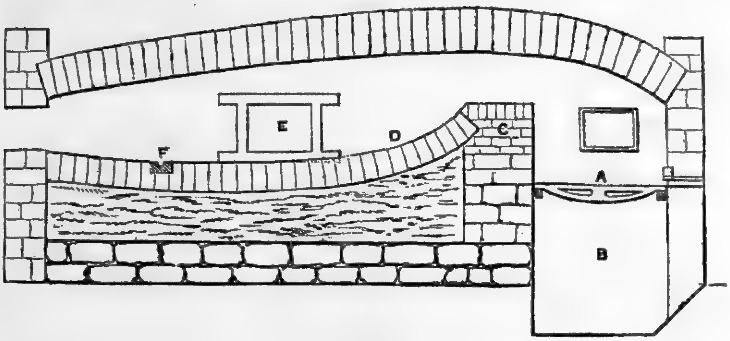
Fresh quantities of litharge, or pot-dross, with small coals, are from time to time thrown in, in proportion as that already charged disappears, and at the end of the shift, which usually extends over 12 hours, the floor of cinder is broken up, and after being mixed with the residual matters in the furnace is withdrawn. A new floor of cinders is then introduced, and the operation commenced as before. A furnace of this kind, having a sole 8 feet in length and 7 feet in width, will afford, from litharge, about 5½ tons of lead in 24 hours.

The dross from the calcining pan, when treated in a furnace of this description, should be previously reduced to a state of fine division, and intimately mixed up with small coal and soda-ash. In many cases, however, the calcined dross is treated in the smelting furnace. The hard lead obtained from this substance is again taken to the calcining furnace, for the purpose of being softened.

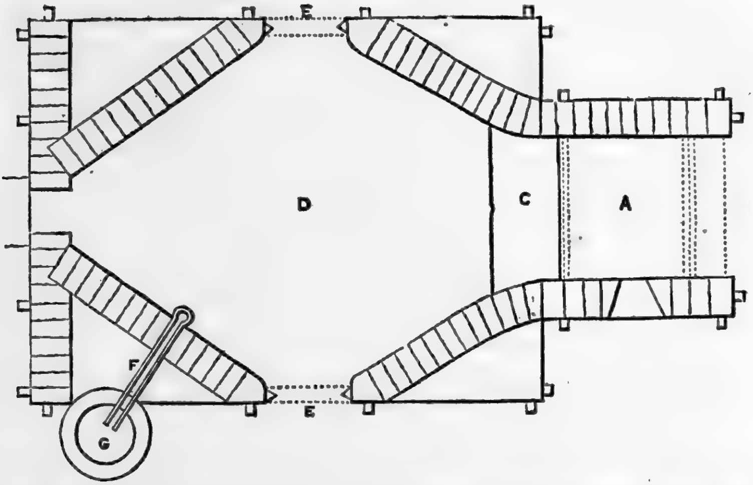
In the establishment from which the foregoing data were obtained, the cost of slack, delivered at the works, was only 2*s.* 11*d.* per ton, which is cheaper than fuel can be obtained in the majority of the lead-mills of this country. In North Wales the cost of small coal is generally about 4*s.*, and at Bristol 5*s.* 6*d.* per ton.

Figs. 1354 and 1355 represent a vertical section and plan of a reducing-furnace. A, fire-place; B, ash-pit; C, fire-bridge; D, hearth; E, working-door; F, iron spout for conducting the reduced metal into the lead-pot G, which is kept heated by means of a fire beneath.

1354



1355



The total cost of elaborating one ton of hard lead, containing 30 oz. of silver per ton, in a locality in which fuel is obtained at the low price above quoted, is nearly as follows :—

	£	s.	d.
Calcining	0	2	4·4
Crystallising	0	9	6·5
Refining	0	0	9·2
Reducing pot dross and litharge	0	1	0·8
Calcined dross	0	0	8·0
Slags	0	0	5·0
Bone-ash, &c.	0	0	7·0
Transport, &c.	0	1	1·0
Management, taxes, and interest of plant	0	5	10·0
Total	1	2	3·9

One hundred tons of hard lead treated gave :—

	Tons.
Soft lead	94·90
Black dross	3·72
Loss	1·38
Total	100·00

On comparing the expense of each operation, as given in the foregoing abstract, with the amounts stated as the cost of each separate process, they will be found to be widely different; but it must be remembered that the whole of the substances elaborated are far from being subjected to the various treatments described.

In order, therefore, to give an idea of the relative proportions which are passed through the several departments, it may be stated that in an establishment in which the ores are treated in the Castilian furnace the following were the results obtained:—

One hundred parts of raw ore yielded:—

Roasted ore	85
Hard lead	42
Soft „	36
Rich „	9
Dross and litharge re-treated	18½

It may be remarked that for the treatment of ores of good produce the reverberatory furnace and Scotch hearth are to be preferred, but for working minerals of a low percentage the blast-furnace may generally be substituted with advantage. The slag-hearth, from the amount of fuel consumed and loss experienced, is a somewhat expensive apparatus, and might in many cases be advantageously exchanged for the Castilian furnace.

It is well known that the losses which take place in this branch of metallurgy are, from the volatility of the metal operated on, unusually large. In those establishments, however, in which due attention is paid to fluxes and a proper admixture of ores, as well as the condensation of the fumes, a great economy is effected.

In some instances flues of above five miles in length have been constructed, and the most satisfactory results obtained. The attention of lead-smelters is being daily more directed to the prevention of the loss of metal by volatilisation, and those who have adopted the use of long flues have been, in all cases, quickly repaid for their outlay.

As an example of the great extent to which sublimation may take place on the scale employed in large smelting works, we may mention the lead-works belonging to Mr. Beaumont in Northumberland. Formerly the fumes or smoke arising from various smelting operations escaped from ordinary chimneys or short galleries, and large quantities of lead were thus carried off in the state of vapour, and deposited on the surrounding land, where vegetation was destroyed, and the health of both men and animals seriously affected. This led to various extensions of the horizontal or slightly-inclined galleries now in use, and the quantity of lead extracted rapidly repaid the cost of construction. The latest addition of this kind was made at Allen Mill, by Mr. Sopwith, the manager, and completed a length of 8,789 yards (nearly five miles) of stone gallery from that mill alone. This gallery is 8 feet high and 6 wide, and is in two divisions, widely separated. There are also upwards of 4 miles of gallery for the same purpose connected with other mills belonging to Mr. Beaumont in the same district, and in Durham. The value of the lead thus saved from being totally dissipated and dispersed, and obtained from what in common parlance might be called chimney-sweepings, considerably exceeds 10,000*l.* sterling annually, and forms a striking illustration of the importance of economising our waste products.

In lieu of long and extensive flues, condensers of various descriptions have from time to time been introduced, but in most instances the former have been found to be more efficient.

When, however, water can be procured for the purpose of cooling the condensers, excellent results are generally obtained.—J. A. P.

See Litharge; Red Lead; Solder; Sugar or *Acetate* of Lead; Type Metal; and White Lead.

Lead Assaying The ores submitted to assay are galena or sulphide of lead, cerussite or carbonate of lead, anglesite or sulphate of lead, and pyromorphite or phosphate of lead. For assay purposes, the ores of lead may be divided into two classes:—

The *first class* comprehends all the ores of lead which contain neither sulphur nor arsenic, or in which they are present in small proportion only.

The *second class* comprises galena, together with all lead ores containing sulphur or arsenic.

A common wind or air furnace is best adapted for making lead assays. For this purpose the cavity for the reception of fuel should be 9 inches square, and the height of the flue-way from the fire-bars about 14 inches. For ordinary ores a furnace 8 inches square and 12 inches deep will be found sufficient; but as it is easy to regulate, by a damper, the heat of the larger apparatus, it is often found advantageous to be able to produce a high temperature. A furnace of this kind should be connected with a chimney of at least twenty feet in height, and be supplied with good coke, broken into pieces of the size of eggs.

The air furnace (see COPPER, *fig.* 533), is well adapted for the assaying of lead ores. The ores should be dried in shallow, flat metal vessels, powdered and sifted through a sieve of from 40 to 60 holes to the linear inch, previous to being submitted to assay. The balance employed should carry 1,000 grs., and turn with $\frac{1}{10}$th of a grain.

The tongs (see COPPER, *fig.* 536) may be used for the assay with earthen crucibles. For working with iron crucibles tongs of stronger and stouter make are desirable. The iron mould (*fig.* 534) is used for receiving the assay products, or one containing a deep conical cavity may be substituted for it. The fluxes should be employed in the dry state.

ORES OF THE FIRST CLASS.—The assay of ores of this class is a simple operation, care being only required that a sufficient amount of carbonaceous matter be added to effect the reduction of the metal, whilst such fluxes are supplied as will afford a readily-fusible slag. When the sample has been properly powdered, 400 or 500 grains are weighed out, and well mixed with 500 or 600 grains of carbonate of soda, and from 40 to 60 grains of finely-powdered charcoal, according to the richness of the mineral operated on. This is introduced into an earthen crucible, of such a size as not to be more than one-half filled by the mixture, and on the top is placed a thin layer of the flux. The crucible is then placed in the furnace and gently heated, care being taken to so moderate the temperature, that the mixture of ore and flux, which soon begins to soften and enter into ebullition, may not swell up and flow over. If the action in the crucible becomes too strong, it must be checked by a due regulation of the heat by means of a damper. When the action has subsided, the temperature is again raised for a few minutes, and the assay completed in about half an hour. During the process of reduction, the heat should not exceed dull redness; but in order to complete the operation, and render the slag sufficiently liquid, the temperature should be raised to bright redness. When the contents have been reduced to a state of tranquil fusion, the crucible must be removed from the fire, and the assay either rapidly poured, or, after being tapped against some hard body to collect the lead in a single globule, be set to cool. When the operation has been successfully conducted, the cooled slag will present a smooth concave surface, with a more or less vitreous lustre. When cold, the crucible may be broken, and the button extracted. To remove from it the particles of adhering slag, it is hammered on an anvil, and afterwards rubbed with a hard brush. Instead of employing carbonate of soda and powdered charcoal, the ore may be fused with 1½ times its weight of black flux, and the mixture covered by a thin layer of borax. Good results are also obtained by mixing together 400 grains of ore with an equal weight of carbonate of soda and half that quantity of crude tartar. These ingredients, after being well incorporated, are placed in a crucible, and slightly covered by a layer of borax. Each of the foregoing methods yields good results, and affords slags retaining but a small proportion of lead.

ORES OF THE SECOND CLASS.—This class comprehends galena, which is the most common and abundant ore of lead, and also comprises sundry metallurgic products, as well as the sulphates and arsenates of lead.

The assay of galena and other substances is variously conducted; but one of the following methods is usually employed for commercial purposes:—

Assay in an earthen crucible with metallic iron.—Mix 400 or 500 grs. of the ore with about an equal weight of carbonate of soda, and, after having placed it in the earthen crucible, of which it should occupy about one half the capacity, insert with their heads downward three or four tenpenny nails, and press the mixture firmly around them. On the top place a thin layer of borax. The whole is now introduced into the furnace, and gradually heated to redness; at the expiration of ten minutes the temperature is increased to bright redness, and the heat continued until the fused fluxes present a perfectly smooth surface. When this has taken place the pot is removed from the fire, and the nails are separately withdrawn by the use of a small pair of tongs, care being taken to well cleanse each in the fluid slag until free from adhering lead. When the nails have been thus removed, the pot is gently shaken, to collect the metal into one button, and laid aside to cool; after which it may be broken, and the button removed. Instead of first allowing the slags to cool, and then breaking the crucible, the assay may, if preferred, after the withdrawal of the nails, be poured into a mould (see COPPER, *fig.* 534). Hoop iron or iron rod may be used, instead of the iron nails. The assay should be completed in from 25 to 30 minutes.

Assay in an iron pot with fluxes.—Instead of adding metallic iron to the mixture of ore and flux, it is generally better that the pot itself should be made of that metal. For this purpose a piece of ½-inch plate iron is turned up in the form of a crucible, and carefully welded at the edges. The bottom is closed by a thick iron rivet, which is securely welded to the sides, and the whole then finished on a properly-formed mandril. To make an assay in a crucible of this kind, it is first heated to dull redness, and, when sufficiently hot, 400 or 500 grs. of the powdered ore, intimately mixed with its own weight of carbonate of soda, half its weight of pearlash, and a small quantity of crude tartar, is introduced by means of a copper scoop (see COPPER, *fig.* 535). On the top of the whole is placed a thin layer of borax, whilst the crucible, which, for the ready introduction of the mixture, has been removed from the fire, is at once replaced. The heat is now raised to redness, the contents gradually becoming liquid, and giving off large quantities of gas. At the expiration of from 8 to 10 minutes the mixture will be in a state of complete fusion; the contents of the pot are now stirred with a small iron rod. Any matter adhering to its sides is scraped to the bottom of the pot, and the temperature of the furnace is increased during 3 or 4 minutes to bright redness.

The crucible is then seized by a strong pair of bent tongs, on that part of the edge which is opposite the lip, and its contents rapidly poured into a cast-iron mould (see COPPER, *fig.* 534). The sides of the pot are now carefully scraped down with a chisel-edge bar of iron, and any adhering particles of metallic lead added to the portion first obtained. When sufficiently cooled the contents of the mould are easily removed, and the button of lead cleaned and weighed. By this process pure galena yields 84 per cent. of metallic lead, free from any injurious amount of iron, and perfectly ductile and malleable. This method of assaying, with various modifications, is that adopted in almost all lead-smelting establishments, and has the advantage of affording good results with all the ores belonging to the second class.

Assay in the iron dish without fluxes.—In some of the mining districts of Wales the assay of lead ore is conducted in a manner somewhat different from that just described. Instead of fusing the ore in an iron crucible with fluxes, the fusion is effected in a flat shallow iron dish, having a hemispherical cavity of about 4½ inches in diameter, and about 1 inch in depth in the centre. 10 oz. of the ore are operated on, and the assay is made by the aid of a blacksmith's forge-fire. The ore is placed in the iron dish, provided with a sheet-iron cover, and heated for about 5 minutes, and the reduced metal poured out into a mould. The iron dish is then replaced on the fire, and the heat continued for about 5 minutes, until the regulus (slurry) is fused; the contents are then poured out into a mould, the lead detached, and added to the first portion of lead obtained; and the whole weighed. Galena will yield as much as 82 per cent. of lead by this method. In some works the assay is made in an iron crucible without fluxes, instead of the iron dish.

Estimation of silver contained in lead ores.—All varieties of lead ore contain silver, and it is consequently necessary, in order to judge of their commercial value, to ascertain the exact amount of this metal which they afford. This is effected by the process of *Cupellation*. See SILVER.

In order, therefore, to separate the silver present in buttons resulting from ordinary lead assays, it is only necessary to expose them, on a *cupel*, to such a temperature as will rapidly oxidise the lead. The oxide of lead, or litharge, produced is absorbed by the porous body on which the assay is supported, and nothing but a small button of silver ultimately remains on the test. These supports or cupels are made of bone-ash, slightly moistened with a little water, and consolidated by being pressed into a mould. The furnace employed for this purpose is described in the article SILVER, as is also the *muffle* or D-shaped retort in which the cupels are heated.

As soon as the muffle has become red hot, the cupels that have been drying in the mouth of the opening are introduced by means of proper tongs, on the bottom of the muffle, previously covered with a thin layer of bone-ash, in order to prevent its being attacked in case of any portion of litharge coming in contact with it during the progress of the subsequent operations. The open end of the muffle is now closed by means of a proper door, and the cupels are thus rapidly heated to the temperature of the muffle itself. When this has been effected the door is removed, and into each of the cupels is introduced, by the aid of slender steel tongs, a button of the lead to be assayed. The mouth of the muffle is again closed during a few minutes to facilitate the fusion of the alloy; when the oxide begins to pass off the surface of the metallic product, the assay is said to be uncovered. The lead is now quickly converted into litharge, which is absorbed by the cupel as fast as it is produced, whilst at the same time there arises a white vapour, which is gradually carried off by the door and through the openings in the sides and end. A circular stain is at the same time formed around the globule of melted metal, which gradually extends and penetrates into the substance of the cupel. When nearly the whole of the lead has thus been removed, the remaining bead of silver appears to become agitated by a rapid motion, which seems to make it revolve with great rapidity. At this stage the motion will be observed suddenly to cease, and the button becomes immoveable. This is called the *brightening* of the assay, and a button of silver now remains on the cupel.

If the cupel were now abruptly removed from the muffle, the globule of silver

Showing the Quantity of Lead Ore raised and smelted, average Metallic Yield of Ore per Cent., and Ratio of Lead produced in various Parts of the United Kingdom, during Ten Years ending 1857.

Years	England		Wales		Ireland		Scotland		Isle of Man		Total	
	Lead Ore	Lead	Lead Ore	Lead	Lead Ore	Lead	Lead Ore	Lead	Lead Ore	Lead	Lead Ore	Lead
	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons
1848 . . .	54,538	39,142	16,305	11,122	1,912	1,188	2,588	1,736	2,521	1,665	77,864	54,853
1849 . . .	60,124	41,168	19,711	13,389	2,739	1,653	1,421	957	2,826	1,535	86,821	58,702
1850 . . .	63,565	44,462	21,093	14,876	2,895	1,746	3,117	2,124	2,175	1,218	92,845	64,426
1851 . . .	64,102	45,108	19,314	14,813	3,222	1,829	3,113	2,140	2,560	1,402	92,311	65,287
1852 . . .	62,411	43,813	18,379	13,798	4,493	3,222	3,499	2,381	2,415	1,835	91,197	64,959
1853 . . .	59,342	41,897	17,131	12,870	3,309	2,452	2,799	1,919	2,460	1,829	85,041	60,967
1854 . . .	64,796	44,986	18,130	13,367	3,069	2,210	1,753	1,279	2,800	2,137	90,548	63,979
1855 . . .	66,270	46,244	18,206	13,673	2,405	1,732	1,587	1,159	3,573	2,725	92,041	65,533
1856 . . .	74,489	52,868	19,873	14,791	2,484	1,602	1,931	1,417	3,218	2,451	101,997	73,129
1857 . . .	68,520	48,356	21,455	16,124	2,299	1,407	1,891	1,351	2,656	2,028	96,821	96,266
	638,157	448,039	189,597	138,733	28,827	19,041	23,699	16,463	27,204	18,825	907,486	644,101
Average metallic yield of ore .	70·2		73·1		66·0		69·4		69·1		70·6	
Ratio of lead produced . .	69·9		21·7		3·0		2·5		2·1		100	

Table of Lead Ores, Lead, and Silver produced from them in the United Kingdom from the year 1848, *showing the Quantity of Ore required to make* 100 *Tons of Lead, the Quantity of Lead in* 100 *Tons of Ore, and the Ounces of Silver in a Ton of Lead, for the same period.*

Years	Lead Ore	Lead	Silver	Ore to make 100 Tons of Lead	Lead in 100 Tons of Ore	Silver in a Ton of Lead
	tons	tons	ozs.	tons	tons	ozs.
1848	78,944	53,373	...	147·909	67·608	...
1849	86,823	58,715	...	147·871	67·626	...
1850	92,958	64,429	...	144·279	69·309	...
1851	92,312	65,289	...	141·389	70·726	...
1852	91,198	64,961	...	140·388	71·230	...
1853	85,843	60,969	496,475	139·485	71·691	8·143
1854	90,554	64,005	562,659	141·479	70·681	8·798
1855	92,251	65,691	561,906	140·430	71·209	8·553
1856	101,997	73,129	614,188	139·476	71·696	8·798
1857	96,820	69,266	532,866	139·780	71·541	7·693
1858	95,855	68,303	569,345	140·377	71·256	8·336
1859	91,353	62,382	578,275	146·441	68·286	9·270
1860	88,791	63,225	549,090	140·436	71·206	8·684
1861	90,666	65,644	570,474	138·117	72·402	8·690
1862	95,312	69,013	686,123	138·107	72·407	9·942
1863	91,283	68,221	634,004	133·804	74·735	9·293
1864	94,463	67,081	641,088	140·819	71·013	9·957
1865	90,452	67,251	724,856	134·499	74·349	10·778
1866	91,051	67,391	636,688	135·108	74·014	9·447
1867	93,432	68,441	805,394	136·514	73·252	11·767
1868	95,236	71,017	841,328	134·103	74·568	11·846
1869	96,866	73,259	831,891	132·224	75·629	11·355
1870	98,176	73,420	784,562	133·718	74·783	10·687
1871	93,965	69,037	761,490	136·108	73·470	11·030
1872	81,564	60,420	628,920	138·89	72·000	10·403

Summary of Lead Ore, Lead, and Silver Produce of 1872.

No. of Mines	Counties	Lead Ore		Lead		Silver
		tons	cwts.	tons	cwts.	ozs.
	ENGLAND:					
18	Cornwall	5,463	10	4,098	15	207,710
5	Devonshire	746	9	522	6	10,392
4	Somersetshire	1,322	5	602	18	...
194	Derbyshire	5,612	0	4,191	2	1,000
2	Staffordshire	280	8	210	11	...
10	Shropshire	7,386	17	5,602	6	2,960
34	Yorkshire	5,202	5	3,873	3	500
30	Cumberland	3,721	17	3,813	2	30,159
7	Westmoreland	1,679	2	1,259	8	17,620
32	Durham and Northumberland	19,106	10	14,399	4	72,175
	WALES:					
1	Breconshire	8	0	6	0	...
40	Cardiganshire	6,764	3	4,998	13	41,690
1	Caermarthenshire	651	0	475	15	2,382
1	Pembrokeshire	130	0	97	10	490
1	Radnorshire	32	13	24	15	125
11	Montgomeryshire	8,059	14	6,042	0	55,712
1	Merionethshire	17	6	13	0	...
6	Denbighshire	3,677	18	2,758	17	14,479
29	Flintshire	3,208	5	2,435	7	18,650
12	Carnarvonshire	397	15	297	1	500
10	Isle of Man	3,529	0	2,639	2	145,433
2	IRELAND	962	0	726	5	1,040
4	SCOTLAND	3,605	5	2,331	7	5,900
455	Total of the United Kingdom	81,564	2	60,420	11	628,920

would be liable to *vegetate*, by which a portion of the metal might be thrown off, and a certain amount of loss be thereby entailed. To prevent this, the cupel in which the assay has brightened should be immediately covered by another, kept red hot for that purpose. The two are now gradually withdrawn together, and, after having sufficently cooled, the upper cupel is removed, and the globule of silver detached and cleaned as follows:—

The globule is now laid hold of by a pair of fine pliers and flattened on a small steel anvil, by which the oxide of lead which may have attached itself to it becomes pulverised, and is removed by rubbing with a small hard brush. The flattened disc is then examined, in order to be sure that it is perfectly clean, and afterwards weighed in a balance capable of turning with $\frac{1}{1000}$th of a grain.

The cupellations should be conducted at the lowest possible heat at which they can be effected. The temperature best fitted for this operation is obtained when the muffle is at a red heat, and the vapours which arise from the assays curl gradually away, and are finally removed by the draught. When the muffle is heated to whiteness, and the vapours rise to the top of the arch, the heat is too great: and when, on the contrary, the fumes lie over the bottom, and the sides of the openings in the muffle begin to darken, either a little more fuel must be added or the draught increased. If an assay has been properly conducted, the button of silver obtained is round, bright, and smooth on its upper surface, and beneath crystalline, and of a dead white colour; easily removed from the cupel, and readily freed from litharge.

When the ores of lead, in addition to silver, contain gold, the button remaining on the cupel is an alloy of these metals. For the method of estimating the gold, see GOLD.

For commercial purposes the silver contained in any given ore is estimated in ounces, pennyweights, and grains troy upon the statute ton avoirdupois of 2,240 lbs. It is customary to return the silver obtained from lead ores upon the ton of lead as yielded by assay, and not upon the ton of ore. For a Table to facilitate calculation, see SILVER.

Lead imported into the United Kingdom in the Year 1872.

Description of Lead	Quantities tons
Lead ore	14,560
Lead, pig and sheet	69,841
Lead manufactures	441

British and Foreign Lead exported in the Year 1872.

Description of Lead	British tons	Foreign tons
Lead ore	1,004	1,404
Pig lead	33,403	691
Lead, rolled, sheet, piping, and tubing	10,927	...
Lead manufactured	...	4

LEAD-SHOT. (*Plomb de Chasse*, Fr.; *Schrot, Flintenschrot*, Ger.) The origin of most of the imperfections in the manufacture of lead-shot is the too rapid cooling of the spherules by their being dropped too hot into the water, whereby their surfaces form a solid crust, while their interior remains fluid, and, in its subsequent concretions, shrinks, so as to produce the irregularities of the shot.

The patent shot-towers originally constructed in England obviate this evil by exposing the fused spherules after they pass through the cullender, to a large body of air during their descent into the water-tub placed on the ground. The highest erection of this kind is probably at Villach in Carinthia, being 240 Vienna, or 249 English feet high.

The quantity of arsenic added to the mass of melted lead varies according to the quality of this metal; the harder and less ductile the lead is, the more arsenic must be added. About 3 pounds of either white arsenic or orpiment is enough for one thousand parts of soft lead, and about 8 for the coarser kinds. The latter are employed preferably for shot, as they are cheaper, and answer sufficiently well. The arsenical alloy is made either by introducing some of this substance at each melting; or by making a quantity of the compound considerably stronger at once, and adding a certain portion of this to each charge of lead. If the particles of the shot appear lens-shaped, it is a proof that the proportion of arsenic has been too great; but if they are flattened upon the side, if they are hollowed in their middle, called *cupping* by the workmen, or drag with a tail behind them, the proportion of arsenic is too small.

The following is the process prescribed by the patentees, Ackerman and Martin. Melt a ton of soft lead, and sprinkle round its sides in the iron pot about two shovelfuls of wood ashes, taking care to leave the centre clear; then put into the middle about 40 pounds of arsenic to form a rich alloy with the lead. Cover the pot with an iron lid, and lute the joints quickly with loam or mortar to confine the arsenical vapours, keeping up a moderate fire to maintain the mixture fluid for three or four hours; after which skim carefully, and run the alloy into moulds to form ingots or pigs. The composition thus made is to be put in the proportion of one pig or ingot into 1,000 pounds of melted ordinary lead. When the whole is well combined, take a perforated skimmer, and let a few drops of it fall from some height into a tub of water. If they do not appear globular, some more arsenical alloy must be added.

Lead which contains a good deal of pewter or tin must be rejected, because it tends to produce elongated drops or tails.

From two to three tons are usually melted at once in the large establishments. The surface of the lead gets covered with a crust of oxide of a white spongy nature, sometimes called *cream* by the workmen, which is of use to coat over the bottom of the cullender, because without such a bed the heavy melted lead would run too rapidly through the holes for the granulating process, and would form oblong spheroids. The mounting of this filter, or lining of the cullender, is reckoned to be a nice operation by the workmen, and is regarded usually as a valuable secret.

The cullenders are hollow hemispheres of sheet-iron, about 10 inches in diameter, perforated with holes, which should be perfectly round and free from burs. These must be of an uniform size in each cullender; but of course a series of different cullenders with sorted holes for every different size of lead-shot must be prepared. The holes have nearly the following diameters for the annexed numbers of shot:—

No. 0.	$\frac{1}{50}$ of an inch.
1.	$\frac{1}{58}$ ”
2.	$\frac{1}{66}$ ”
3.	$\frac{1}{72}$ ”
4.	$\frac{1}{80}$ ”

From No. 5 to No. 9 the diameter decreases by regular gradations, the latter being only $\frac{1}{360}$th of an inch.

The operation is always carried on with three cullenders at a time, which are supported upon projecting grates of a kind of chafing-dish made of sheet-iron somewhat like a triangle. This chafing-dish should be placed immediately above the fall, while at its bottom there must be a tub half-filled with water for receiving the granulated lead. The cullenders are not in contact, but must be parted by burning charcoal in order to keep the lead constantly at the proper temperature, and to prevent its solidifying in the filter. The temperature of the lead-bath should vary with the size of the shot; for the largest, it should be such that a bit of straw plunged into it will be scarcely browned, but for all it should be nicely regulated. The height from which the particles should be let fall varies likewise with the size of the shot; as the congelation is the more rapid, the smaller they are. With a fall of 33 yards or 100 feet, from No. 4 to No. 9 may be made: but for larger sizes, 150 feet of height will be required.

Everything being arranged as above described, the workman puts the filter-stuff into the cullender, pressing it well against the sides. He next pours lead into it with an iron ladle, but not in too great quantity at a time, lest it should run through too fast. The shot thereby formed and found in the tub are not all equal.

The centre of the cullender being less hot affords larger shot than the sides, which are constantly surrounded with burning charcoal. Occasionally, also, the three cullenders employed together may have holes of different sizes, in which case the tub may contain shot of very various magnitudes. These are separated from each other by square sieves of different fineness, 10 inches broad and 16 inches long, their bottoms being of sheet-iron pierced with holes of the same diameters as those of the cullenders. These sieves are suspended by means of two bands above boxes for receiving the shot; one sieve being usually set above another in consecutive numbers, for instance, 1 and 2. The shot being put into the upper sieve, No. 0 will remain in it; No. 1 will remain in the lower sieve, and No. 2 will, with all the others, pass through it into the chest below. It is obvious that by substituting sieves of successive fineness, shot of any dimensions may be sorted.

In the preceding process the shot has been sorted to size; it must next be sorted to form, so as to separate all the spheroids which are not truly round, or are defective in any respect. For this purpose a board is made use of about 27 inches long and 16 broad, furnished partially with upright ledges; upon this tray a handful or two of the shot to be sorted being laid, it is inclined very slightly, and gently shaken in the horizontal direction, when the globular particles run down by one edge, into a chest set to receive them, while those of irregular forms remain on the sides of the tray, and are reserved to be re-melted.

After being sorted in this way, the shot requires still to be smoothed and polished bright. This object is effected by putting it into a small octagonal cask, through a door in its side, turning upon a horizontal iron axis, with rests in plummer boxes at its ends, and is made to revolve by any mechanical power. A certain quantity of plumbago or black-lead is put into the cask along with the shot.

LEAD, SALTS OF. The following are the chief artificial salts:—

CARBONATE OF LEAD. See WHITE LEAD.

NITRATE OF LEAD (*Nitrate de plomb*, Fr.; *Salpetersäures bleioxyd*, Ger.), is made by saturating somewhat dilute nitric acid with oxide of lead (litharge), evaporating the neutral solution till a pellicle appears, and then exposing it in a hot chamber till it be converted into crystals, which are sometimes transparent, but generally opaque white octahedrons. Their spec. grav. is 4·068; they have a cooling, sweetish, pungent taste. They dissolve in 7 parts of cold, and in much less boiling water; they fuse at a moderate elevation of temperature, emit oxygen gas, and pass into oxide of lead. Their constituents are 67·3 oxide and 32·7 acid. Nitrate of lead is much employed in the chrome-yellow style of CALICO-PRINTING.

There are three other compounds of nitric acid and lead oxide: viz. the bi-basic, the tri-basic, and the sex-basic; which contain respectively 2, 3, and 6 atoms of base to 1 of acid.

OXYCHLORIDE OF LEAD.—A white pigment patented by the late Mr. Hugh Lee Pattinson, of Newcastle, which he prepared by precipitating a solution of chloride of lead in hot water with pure lime-water, in equal measures; the mixture being made with agitation. As the operation of mixing the lime-water and the solution of chloride of lead requires to be performed in an instantaneous manner, the patentee prefers to employ for this purpose two tumbling boxes of about 16 feet cubic capacity, which are charged with the two liquids, and simultaneously upset into a cistern in which oxychloride of lead is instantaneously formed, and from which the mixture flows into other cisterns, where the oxychloride subsides. This white pigment consists of one atom of chloride of lead and one atom of oxide of lead, with or without an atom of water.

The salts of lead, beyond those already named, which enter into any of our manufactures, are few and unimportant. Watts's *Dictionary of Chemistry* should be consulted for them.

LEAD, RED. See Red Lead.

LEAD, WHITE. See White Lead.

LEADHILLITE. A sulphato-carbonate of lead found at Leadhills, in Lanarkshire, Scotland.

LEATHER (*Cuir*, Fr.; *Leder*, Ger.; *Leer*, Dutch; *Læder*, Danish; *Läder*, Swedish; *Cuojo*, Italian; *Cuero*, Spanish; *Kusha*, Russian). This substance consists of the skins of animals, chemically changed by the process called *tanning*. Throughout the civilised world, and from the most ancient times this substance has been employed by man for a variety of purposes. Barbarous and savage tribes use the skins of beasts as *skins*; civilised man renders the same substance unalterable by the external agents which tend to decompose it in its natural state, and by a variety of peculiar manipulations prepares it for almost innumerable applications.

Although the preparation of this valuable substance in a rude manner has been known from the most ancient times, it was not until the end of the last, and the beginning of the present century (1800) that it began to be manufactured upon right principles, in consequence of the researches of Macbride, Deyeux, Seguin, and Davy.

Skins may be converted into leather either with or without their hair; generally, however, the hair is removed.

The most important and costly kinds are comprised under sole leather and upper leather, to which may be added harness leather, belts used in machinery, leather hose, &c., but as far as the tanner is concerned, these are comprehended almost entirely in the kinds known as upper leather.

The active principle by which the skins of animals are prevented from putrefying, and at the same time, under some modes of preparation, rendered comparatively impervious to water, is called tannin, or tannic acid, a property found in the bark of the various species of *Quercus*, but especially plentiful in the gall-nut. When obtained pure, as it may easily be from the gall-nut, by chemical means, tannic acid appears as a slightly yellowish, almost a colourless mass, readily soluble in water; it precipitates gelatin from solution, forming what has been called *tannogelatin*. Tannic acid also precipitates albumen and starch. There can be little difficulty, after knowing the chemical combination just alluded to, in understanding the peculiar and striking change produced on animal substance in the formation of leather. The hide or skin consists principally of gelatin, for which the vegetable astringent tannin has an affinity, and the chemical union of these substances in the process of tanning produces the useful article of which we are treating.

Before entering upon the various processes by which the changes are effected on the animal fibre, it may not be uninteresting to speak of some of the principal astringents used for the purpose of producing these effects.

Bark obtained from the oak-tree is the most valuable and the most extensively used ingredient in tanning, and for a long time no other substance was used in England for the purpose. In consequence of the demand having become very much greater than the supply, and the consequent increase in the price of the article, it became necessary to investigate its properties, in order, if possible, to furnish the required quantity of tanning matter from other sources. Among other substitutes which were tried with some success in other countries may be mentioned *heath, myrtle leaves, wild laurel leaves, birch-tree bark*, and (according to the 'Penny Cyclopædia') in 1765 oak-sawdust was applied in England, and has since been used in Germany for this purpose.

Investigation proved that the tanning power of oak-bark consisted in a peculiar astringent property, to which the name of *tannin* has been given, and this discovery suggested that other bodies possessing this property would be suitable substitutes.

According to Sir H. Davy the following proportions of tannin in the different substances mentioned will be found:—'8½ lbs. of oak-bark are equal to 2¼ lbs. of galls, to 3 lbs. of sumach, to 7½ lbs. of bark of Leicester willow, to 11 lbs. of the bark of the Spanish chestnut, to 18 lbs. of elm-bark, and to 21 lbs. of common willow-bark.'—*Penny Cyclopædia.*

Oak-bark contains more tannin when cut in spring by four and a half times than when cut in winter; it is also more plentiful in young trees than in old ones. About 40,000 tons of oak-bark are said to be imported into this country annually, from the Netherlands, Germany, and ports in the Mediterranean. The quantity of English oak-bark used we have no means of ascertaining. It is prepared for use by grinding it to a coarse powder between cast-iron cylinders, and laid into the tan-pits alternately with the skins to be tanned. Sometimes, however, as will be hereafter noticed, an infusion of the bark in water is employed with better effect. See Oak-Bark.

Mimosa.—The bark and pods of several kinds of *Prosopis*, the astringent properties of which have rendered them valuable in tanning, are known in commerce by this name. The *Mimosæ* are a division of the leguminous order of plants, which consists of a large number of species, the Acacia being the principal. The sensitive plants belong to this division. The *Prosopis* is found in India and South America; the genus consists both of shrubs and trees.

Valonia.—The oak which produces this acorn is the *Quercus Ægilops*, or great prickly-cupped oak (*figs.* 1356, 1357). These are exported from the Morea and Levant; the husk contains an abundance of tannin.

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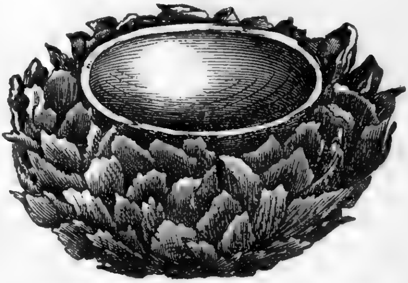


Catechu, or *Terra Japonica*, is the inspissated extract of the *Acacia catechu*. At the time the sap is most perfectly formed the bark of the plant is taken off, the tree is then felled, and the outer part removed; the heart of the tree, which is brown, is cut into pieces and boiled in water; when sufficiently boiled it is placed in the sun, and, subject to various manipulations, gradually dried. It is cut into square pieces, and much resembles a mass of earth in appearance; indeed, it was once considered to be such, hence the name *Terra Japonica*.

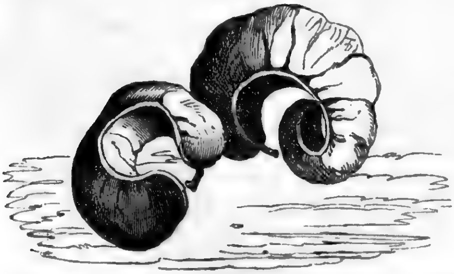
We give Sir H. Davy's analysis; the first numbers represent Bombay, the second Bengal catechu:—

Tannin	109	97
Extractive	68	73
Mucilage	13	16
Impurities	10	14

This astringent is also obtained from the *Uncaria Gambir*.

Dividivi is a leguminous plant of the genus *Cæsalpinia* (*C. coriaria*). The legumes of this species are extremely astringent, and contain a very large quantity of tannic and gallic acid; they grow in a very peculiar manner, and become curiously curled as they arrive to perfection (*fig.* 1358). The plant is a native of America, between the tropics.

1358



Sumach is a plant belonging to the genus *Rhus*; several of the species have astringent properties; *Rhus cotinus* and *R. coriaria* are much used in tanning; the bark of the latter is said to be the only ingredient used in Turkey for the purpose of converting gelatin into leather. That used in this country is ground to a fine powder, and is extensively applied to the production of bright leather, both by tanners and curriers.

Many other vegetable products have been from time to time proposed, and to some extent adopted for the same end, but they need not be enumerated.

The process first attended to by the tanner is simply to soak the skin or hide in water; those from the home market may be said to be washed merely, as they remain in water only a few hours; while hides imported from foreign countries, and which have been preserved by salting or drying, *and especially the latter*, require soaking for a longer period, in order to render them supple, and beating or rubbing materially assists in bringing them to the required condition.

After removing the horns, the softened or recent hides are laid in a heap for a short time, after which they are suspended on poles in a close room called a smoke-house, heated somewhat above the common temperature by a smouldering fire. In these circumstances, a slight putrefaction supervenes, which loosens the epidermis, and renders the hair easily detachable. This method for removing the hair is by no means general in this country. The plan adopted is to place the hides in a large vat or pit, containing milk of lime, in which they must be moved frequently, to allow the lime to act equally on every part. When the menstruum has taken proper effect, the hair is easily removed, and for this purpose the hide is spread out, and a blunt tool is worked over the surface. The hair being removed, the hide is washed in water to cleanse it from the lime, which must be most thoroughly effected.

The heaviest hides are for the most part tanned for sole leather, and as the thinner parts are cut off previous to their being prepared for sale, they have received the name of *butts* or *backs*: the various processes through which these pass will be first described.

After removing the hair and washing, the hides are placed on a convex beam (*fig.* 1359), and worked with a concave tool with two handles (*fig.* 1360), in order to remove any flesh or fatty matter which may adhere to them; this being done, they are worked on the same beam, on the grain side, to drive out the grease and remove any remaining hair. The *fleshings* are pressed into cakes, and sold for making glue, as are all such portions of the hide or skin as cannot be conveniently worked. The hair is sold to plasterers, to be used in their mortar; and the tails, also for the hair, to sofa-makers and others requiring such materials.

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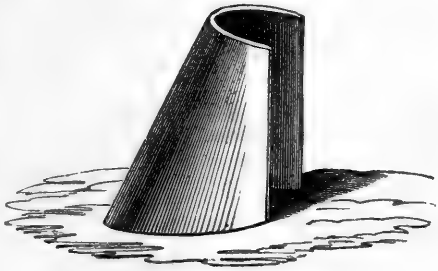

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Such hides as are designed for machinery purposes are next immersed in a pit containing water impregnated with sulphuric acid, the acid varying from $\frac{1}{500}$th to $\frac{1}{1000}$th of the mixture. This process is called *raising*, because it distends the pores, and makes the fibres swell, so as to become more susceptible of the action of tanning infusions. Forty-eight hours in general suffice for this operation, but more time may be safely taken. From the term *raising* it will be concluded that the substance of the hide is increased, and this is the fact; but as the gelatine is not increased, it is said that the shoemaker's hammer would condense the leather so much that it would lose any supposed advantage arising out of this increase in thickness. There is, however, a method of augmenting the substance of sole leather called *puffing*, which, when once communicated, appears to exist permanently; the process is known to a small extent only, and the material is said to be considerably injured by this mode of preparation.

When the hides are sufficiently *raised*, they are transferred to a pit supplied with a weak infusion of bark; here they are *handled*, at first several times a day; that is, they are drawn out of the pits, or moved up and down in the *liquor*, to prevent the grain from being drawn into wrinkles. As the *ooze*, or tanning infusion, takes effect, they are put into pits containing stronger liquors, and after a month or six weeks they are placed in a pit, in which they are stratified with oak-bark, ground by a proper mill into a coarse powder. The pit is then filled with an infusion of bark. In a month or five weeks the tanning and extractive matter of the bark will have intimately combined with the animal fibre; the pit, exhausted of its virtue, must be renewed by taking out the spent bark, and repeating the dose as in the first instance. The hides, which were placed at the top of the pit at first, are now put into the bottom, to equalise the action. In about three months this also is spent, and the process being repeated two or three times more, the operation is complete. The hides are now removed from the pit, and hung up in a shed. In the progress of drying they are compressed with a steel tool, and afterwards they are subjected to the action of a brass roller. The steel tool is called a *pin*; it is of a triangular shape (*fig.* 1361), with the sides scooped out (*fig.* 1362), presenting three blunt edges. The butt is thrown across a pole, and the workman, taking the pin by the handles *a*, *a* (*fig.* 1361), presses it forcibly over the grain-side of the leather; after carefully compressing every part in this way, the *butt* is laid upon a flat bed of solid wood-work, prepared for the purpose, and the brass roller is worked backward and forward until every portion is sufficiently compressed

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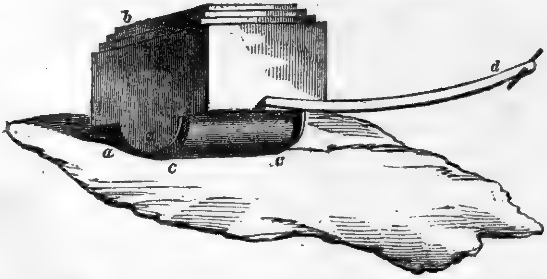

(*fig.* 1363). The roller *a* is a cylinder varying from 9 to 12 inches in length, and from 7 to 10 inches in diameter; *b* is an open box over the roller, into which weights are placed to make the necessary pressure, ten or twelve cwts. being frequently used for the purpose; *c, c,* forms a fulcrum for lifting the roller from the bed to the leather; *d* is the handle by which the machine is worked. When the compression is completed, the only thing remaining to be done is properly to dry the leather, and then it is fit for the market.

Some manufacturers place on the bottom of the tan-pit five or six inches of spent bark, and two or three inches of fresh bark over it, then a hide, and so alternately bark and a hide, until the pit is nearly full, reserving a small space at the top for a thicker layer of bark, over which weighted boards are laid, to condense the whole down into the tanning infusion.

The operation of tanning sole leather by the above method occupies a year or more, the time depending on the nature and stoutness of the hide.

A perfect leather is recognised by its section, which should have a glistening marbled appearance, without any white streak in the middle.

Crop hides are manufactured very much like butts, that is to say, they are placed in milk of lime until the hair is sufficiently loosened, equality of action being secured by occasionally moving them in the menstruum; they are then cleared of the hair and other impurities by the *fleshing knife,* worked on the convex beam already described, they are then freed from lime by thorough washing. The next process is to plunge them into a weak ooze, from which they are transferred to other pits with stronger ooze; all the while they are frequently *handled,* that is, moved up and down in the infusion. After a month or six weeks they are subjected to a mixture of ground oak-bark and stronger ooze in other pits, to a series of which they are progressively subjected during two or three months.

The hides are next put into large vats called *layers,* in which they are smoothly stratified, with more bark and a stronger infusion. After about six weeks they are taken out of these vats, and subjected to a new charge of this material, and allowed to lay some two months; this process is repeated once or twice more till the hides are thoroughly tanned. They are then slowly dried in the shed, and folded for market. Although in general the stoutest and most compact hides are used as sole leather (notwithstanding that they have not been condensed by the tanner, as in the case of *butts*), yet many are appropriated to other purposes by the currier, and the lighter cow-hides are manufactured for the upper leather of stout shoes, water-boots, &c.

The process of tanning *skins* (as calves, seals, &c.) next claims attention. These are placed in the lime-pits until the hair can be easily removed, a process which requires about ten or twelve days; this being accomplished, they are next washed in water, so as completely to remove the lime, as far as washing can secure its removal, and then immersed in a lixivium of pigeon's dung, dog's dung, or matters of a like nature; in this state they remain about ten or twelve days, the state of the atmosphere rendering the process quicker at one time than another; here also they are frequently handled, and *worked* on both sides on the convex beam. The working, joined to the action of the peculiar lixivium, serves to separate the remaining lime, oil, and glutinous matter, and at the same time to render the skin pliant, soft, and ready to imbibe the tanning principle. It is important that great attention should be paid to the process just described, as too short a period would produce a hard and crisp leather, while a few hours more than is necessary makes the article coarse and spongy, both of which conditions should be very carefully guarded against.

The skins are next removed to a pit containing a weak solution of bark, in which they undergo nearly the same treatment as *crop hides*, but they are not commonly stratified in the layers. About three months is usually occupied in tanning calf-skins, but of course the stouter the skin the more will be the time required. When dried they are disposed of to the currier, who dresses them for the upper leathers of boots, shoes, and a variety of other purposes. It is not unusual for the lighter *cow hides* to be treated like calf-skins.

Horse-hides are also treated like calf-skins; but as the horse-hide, with the exception of the part on and near the animal's rump, produces a thin leather, it is usual, before subjecting the hide to the action of the bark, to cut out what is called the *butt*, which is tanned separately, and frequently used as an inferior sole leather. It is also to be remarked that horse-hides and *kips* (the hides of small foreign cattle) are frequently subjected to a process called *bate shaving*, in which the stout parts are reduced by a *currier's* knife previous to tanning, the object being to secure the complete infiltration of the animal fibre by the tannin in every part of the hide in the same time.

Sheepskins are usually pressed after the wool is removed, and before the tanning process is commenced, to get rid of the fatty matter contained in them, and which is not readily removed by ordinary *working*.

In all the above processes, as the animal fibres on the surface of the skin absorb most readily the tanning principles, and thereby obstruct, in a certain degree, their passage into the interior fibres, especially of thick hides, it becomes an object of importance to contrive some method of overcoming that obstacle, and promoting the penetration of the tan. The first manufacturer who appears to have employed efficacious mechanical means for favouring the chemical action was Francis G. Spilsbury, who, in April 1823, obtained a patent for the following operation:—After the hides are freed from the hairs, &c., in the usual way, they are minutely inspected as to their soundness, and if any holes be found, they are carefully sewed up, so as to be water-tight. Three frames of wood are provided of equal dimensions, fitted to each other, with the edges of the frames held together by screw bolts. A skin about to be tanned is now laid upon the frame, and stretched over its edges, then the second frame is to be placed upon it, so that the edges of the two frames may pinch the skin all round and hold it securely; another such skin is then stretched over the upper surface of the second frame, in like manner, and a third frame being set upon this, confines the second skin. The three frames are then pinched tightly together by a series of screw bolts, passing through ears set round their outer edges, which fix the skin in a proper manner for being operated upon by the tanning liquor.

A space has been thus formed between the two skins, into which, when the frames are set upright, the infusion is introduced by means of a pipe from the cistern above, while the air is permitted to escape by a stopcock below. This cock must of course be shut whenever the bag is filled, but the one above is left open to maintain a communication with the liquor cistern, and to allow the hydrostatic pressure to force the liquor through the cutaneous pores by a slow infiltration, and thus to bring the tannin into contact with all the fibres indiscriminately. The action of this pressure is evinced by a constant perspiration on the outer surfaces of the skins.

When the tanning is completed, the upper stopcock is closed, and the under is opened to run off the liquor. The frames are now removed, the bolts are unscrewed, and the pinched edges of the skins pared off; after which they are to be dried and finished in the usual manner.

A modification of this ingenious and effectual process was made the subject of a patent, by William Drake, of Bedminster, tanner, in October 1831. The hides, after the usual preparatory processes, are immersed in a weak tan liquor, and by frequent handling or turning over, receive an incipient tanning before being submitted to the infiltration plan. Two hides, as nearly of the same size and shape as possible, are placed grain to grain, when their corresponding edges are sewed firmly together all round by shoemaker's waxed thread, so as to form a bag sufficiently tight to hold tan liquor. This bag must then be suspended by means of loops sewed to its shoulder-end, upon pegs, in such a manner that it may hang within a wooden-barred rack, and be confined laterally into a book form. About an inch of the bag is left unsewed at the upper end, for the purpose of introducing a funnel through which the cold tan liquor is poured into the bag till it be full. After a certain interval, which varies with the quality of the hides, the outer surface becomes moist, and drops begin to form at the bottom of the bag. These are received in a proper vessel, and when they accumulate sufficiently may be poured back into the funnel; the bag being thus, as well as by a fresh supply from above, kept constantly distended.

When the hides are observed to feel hard and firm, while every part of them feels equally damp, the air of the tanning apartment, having been always well ventilated, is now to be heated by proper means to a temperature gradually increasing from 70° to 150° of Fahrenheit's scale. This heat is to be maintained till the hides become firmer and harder in all parts. When they begin to assume a black appearance in some parts, and when the tan liquor undergoes little diminution, the hides may be considered to be tanned, and the bag may be emptied by cutting a few stitches at its bottom. The outer edges being pared off, the hides are to be finished in the usual way. During their suspension within the racks, the hides should be shifted a little sideways, to prevent the formation of furrows by the bars, and to facilitate the equable action of the liquor.

By this process the patentee says, that a hide may be tanned as completely in ten days as it could be in ten months by the usual method.

Messrs. Knowlys and Duesbury obtained a patent in August 1826 for accelerating the impregnation of skins with tannin, by suspending them in a close vessel, from which the air is to be extracted by an air-pump, and then the tanning infusion is to be admitted. In this way, it is supposed to penetrate the hide so effectually as to tan it uniformly in a short time.

Danish leather is made by tanning lamb and kid skins with willow bark, whence it derives an agreeable smell. It is chiefly worked up into gloves.

Of the tawing or dressing of skins for gloves, and white sheep leather.

The operations of this art are: 1, washing the skins; 2, properly treating them with lime; 3, taking off the fleece; 4, treatment in the leather steep.

A shed erected upon the side of a stream, with a cistern of water for washing the skins; wooden horses for cleaning them with the back of the fleshing knife; pincers for removing the fibres of damaged wool; a plunger for depressing the skins in the pits; a lime pit; a pole with a bag tied to the end of it; a two-handled fleshing knife; a rolling pin, from 15 to 18 inches long, thickened in the middle;—such are some of the utensils of a tawing establishment. There must be provided also a table for applying the oil to the skins; a fulling mill, worked by a water-wheel or other power; a dressing peg; a press for squeezing out the fatty filth; a stove; planks mounted upon legs, for stretching the skins, &c.

Fresh skins must be worked immediately after being washed, and then dried, otherwise they ferment, and contract either indelible spots, or get tender in certain points, so as to open up and tear under the tools. When received in the dry state they should be steeped in water for two days, and then treated as fresh skins. They are next strongly rubbed on the convex horse-beam with a round-edged knife, in order to make them pliant. The rough parts are removed by the fleshing knife. One workman can in this way prepare 200 skins in a day.

The flesh side of each being rubbed with a cold cream of lime, the skins are piled together with the woolly side of each pair outermost, and the flesh sides in contact. They are left in this state for a few days, till it is found that the wool may be easily removed by *plucking*.

They are next washed in running water, to separate the greater part of the lime, stripped of the wool by small spring tweezers, and then fleeced smooth by means of the rolling pin, or sometimes by rubbing with a whetstone. Unless they be fleeced soon after the treatment with lime, they do not well admit of this operation subsequently, as they are apt to get hard.

They are now steeped in the milk-of-lime pit, in order to swell, soften, and cleanse them; afterwards in a weak pit of old lime-water, from which they are taken out and drained. This steeping and draining upon inclined tables, are repeated frequently during the space of three weeks. Only the skins of young animals, or those of inferior value are tawed. Sometimes the wool is left on, as for housings, &c.

The skins, after having been well softened in the steeps, are rubbed on the outside with a whetstone set in a wooden case with two handles, in order to smoothe them completely by removing any remaining filaments of wool. Lamb-skins are rubbed with the pin in the direction of their breadth, to give them suppleness; but sheep-skins are fulled with water alone. They are now ready for the *branning*, which is done by mixing 40 lbs. of bran with 20 gallons of water, and keeping them in this fermentable mixture for three weeks—with the addition, if possible, of some old bran-water. Here they must be frequently turned over, and carefully watched, as it is a delicate operation. In the course of two days in summer, and eight in winter, the skins are said to be *raised*, when they sink in the water. On coming out of the bran they are ready for the white stuff; which is a bath composed of alum and sea-salt. Twelve, fourteen, and sometimes eighteen pounds of alum for 100 skins, form the basis of the bath; to which two and a half pounds of salt are added in winter, and three in summer. These ingredients are introduced into a copper with twelve gallons of water. The salt aids in the whitening action. When the solution is about to boil, three gallons of it are passed through the cullender into a basin; in this 26 skins are worked one after another, and, after draining, they are put together into the bath, and left in it for ten minutes to imbibe the salts. They are now ready to receive the paste. For 100 skins, from 13 to 15 pounds of wheat-flour are used, along with the yolks of 50 eggs. After having warmed the alum-bath through which the skins have been passed, the flour is dusted into it, with careful stirring. The paste is well kneaded by the gradual addition of the solution, and passed through the cullender, whereby it becomes as clear as honey. To this the yolks being added, the whole is incorporated with much manual labour. The skins are worked one after another in this paste; and afterwards the whole together are left immersed in it for a day. They are now stretched and dried upon poles, in a proper apartment, during from 8 to 15 days, according to the season.

The effects of the paste are to whiten the skins, to soften them, and to protect them from the hardening influence of the atmosphere, which would naturally render them brittle. They would not bear working upon the *softening iron*, but for the emulsion which has been introduced into their substance. With this view they are dipped in a tub of clear water during five or six minutes, and then spread and worked upon the board. They are increased by this means in length, in the proportion of 5 to 3. No hard points must be left in them. The whiteness is also better brought out by this operation, which is performed upon the flesh side. The softening tool is an iron plate, about 1 foot broad, rounded over above, mounted upon an upright beam, 30 inches high, which is fixed to the end of a strong horizontal plank, 3½ feet long and 1 broad. This plank is heavily loaded, to make it immoveable upon the floor. Sometimes the skins are next spread over an undressed clean skin upon the horse, and worked well with the two-handled knife, for the purpose of removing the first and second epidermis, called the *fleur* and *arrière-fleur* by the French *mégissiers*. They are then dried while stretched by hooks and strings. When dry they are worked on the *stretching-iron*, or they are occasionally polished with pumice-stone. A delicate yellow tint is given by a composition made of two parts of whitening and one of ochre, applied in a moistened state, and well worked in upon the grain side. After being polished with pumice, they are smoothed with a hot iron, as the laundresses do linen, whereby they acquire a degree of lustre, and are ready to be delivered to the *glover*.

For *housings*, the best sheep-skins are selected, and such as are covered with the longest and most beautiful fleece. They are steeped in water, in order to be cleaned and softened; after which they are thinned inside by the fleshing knife. They are now steeped in an old bran-pit for 3 or 4 days, when they are taken out and washed. They are next subjected to the white or alum-bath, the wool being carefully folded within; about 18 lbs. of alum being used for 100 skins. The paste is made as for the fleeced skins, but it is merely spread upon their flesh side, and left upon them for 18 hours, so as to stiffen. They are then hung up to dry. They are next moistened by sprinkling cold water upon them, folded up, piled in a heap, and covered with boards weighted with heavy stones; in which state they remain for two days. They are next opened with a round iron upon the horse, and subjected to the stretching iron, being worked broadwise. They are dried with the fleece outermost, in the sun if possible, and are finished upon the *stretcher*.

Calf- and lamb-skins with their hair and wool are worked nearly in the same manner; only the thicker the skin, the stronger the alum-bath ought to be. One pound of alum and one of salt are required for a single calf-skin. It is left four days in this bath, after which it is worked upon the *stretcher*, and then fulled. When half dry, the skins are opened upon the horse. In eight days of ordinary weather, they may be completely dressed. Lamb-skins are sometimes steeped during eight days in a bath prepared with unbolted rye-flour and cold water, in which they are daily moved about two or three times. They are then dried, stretched upon the iron, and switched upon the fleecy side.

Chamois, or *Shamoy leather*.—The skins are first washed, limed, fleeced, and branned as above described. They are next *efflowered*, that is, deprived of their epidermis by a concave knife, blunt in its middle part, upon the convex horse-beam. The cutting part serves to remove all excrescences, and to equalise the thickness, while the blunt part softens and smooths. The skins of goats, does, and chamois are always treated in this way. They are next subjected to the fermenting bran-steep for one or two days, in ordinary weather; but in hot weather for a much shorter time, sometimes only moving them in the sour bran-liquor for a few minutes. They are lastly wrung at the peg, and subjected to the fulling mill.

When the skins have been sufficiently swelled and suppled by the branning, they may receive the first oil as follows: a dozen skins being stretched upon the table, the fingers are dipped in the oil, and shaken over the skins in different places, so as to impart enough of it to imbue the whole surface slightly, by friction with the palms of the hands. It is to the outside or *grain* that the oil is applied. The skins are folded four together, so as to form balls of the size of a hog's bladder, and thrown into the trough of the fulling mill, to the number of twelve dozen at once. Here they remain exposed to the beater for two, three, or four hours, according to their nature and the state of the weather. They are taken out, aired, oiled, and again fulled. The airing and fulling are repeated several times, with more or less frequent oilings. Any cheap animal oil is employed.

After these operations, the skins require to be subjected to a fermenting process, to dilate their pores, and to facilitate their combination with the oil. This is performed in a chamber only 6 feet high and 10 or 12 feet square. Poles are suspended horizontally a few inches from the ceiling, with hooks fixed in them to which the skins are attached. A somewhat elevated temperature is maintained, and by a stove if need be. This operation requires great skill and experience.

The remainder of the epidermis is next removed by a blunt concave knife and the horse; whereby the surface is not cut, but rather forcibly scraped.

The skins are now scoured to carry off the redundant oil; which is effected by a potash-lye, at 2° Baumé, heated no hotter than the hand can bear. In this they are stirred briskly, steeped for an hour, and lastly wrung at the peg. The soapy liquor thus expelled is used for inferior purposes. The clean skins after being dried are finished first on the *stretcher-iron*, and then on the *horse* or stretching frame.

Leather of Hungary.—This is manufactured by impregnating strong hides with alum, common salt, and suet; by a rapid process which is usually completed in the space of two months. The workshop is divided into two parts: 1. A shed on the side of a stream, furnished with wooden horses, fleshing knives, and other small tools. In one corner is a furnace with a boiler for dissolving the alum, a vat for immersing the hides in the solution, and several subsidiary tubs. 2. A chamber, 6 feet high, by 15 feet square, capable of being made very tight, for preserving the heat. In one corner is a copper boiler, of sufficient size to contain 170 lbs. of tallow. In the middle of the stove is a square stone slab, upon which an iron grate is placed about a yard square. This is covered with charcoal. At each side of the stove are large tables, which occupy its whole length, and on which the leather is spread to receive the grease. The upper part below the ceiling is filled with poles for hanging the leather upon to be heated. The door is made to shut perfectly close.

The first operations are analogous to those of tanning and tawing; the skins being washed, cut in halves, shaved, and steeped for 24 hours in the river. They are then cleaned with 5 or 6 lbs. of alum, and 3½ lbs. of salt, for a piece of hide which weighs from 70 to 80 lbs. The common salt softens the effect of the alum, attracts the moisture of the air, and preserves the suppleness of the skin. When the alum and salt are dissolved, hot water is poured upon the hides placed in a vat, and they are trampled upon by a workman walking repeatedly from one end of the vat to the other. They are then transferred into a similar vat containing some hot water, and similarly trampled upon. They are next steeped for eight days in alum-water. The same round of operations is repeated a second time.

The skins are now dried either in the air, or in a stove-room; but before being quite dry, they are doubled together, well stretched to take out the wrinkles, and piled up. When dry, they are again trampled to open the pores as well as to render the skin pliant, after which they are whitened by exposure to the sun.

Tallow of inferior quality is employed for greasing the leather. With this view the hides are hung upon the poles in the close stove-room, then laid upon the table, and besmeared with the tallow melted till it begins to crackle. This piece is laid on another table, is there covered with a second, similarly greased, and so forth. Three pounds of fat are commonly employed for one piece of leather.

When the thirty strips, or fifteen hides passed through the grease in one operation are completed, two workmen take the first piece in their hands, and stretch it over the burning charcoal on the grate for a minute, with the flesh-side to the fire. The rest are passed over the flame in like manner. After *flaming*, the pieces are successively laid on an inclined table exposed to the fire, where they are covered with a cloth. They are finally hung upon poles in the air to dry; and if the weather be warm, they are suspended only during the night, so as to favour the hardening of the grease. Instead of the alum-bath, M. Curaudau has employed with advantage a steep of dilute sulphuric acid.

The Russians have long been possessed of a method of making a peculiar leather, called by them *Jucten*, dyed red with the aromatic saunders wood. This article has been much sought after, on account of not being subject to mould in damp situations, being proof against insects, and even repelling them from the vicinity by its odour. The skins are freed from the hair or fleece, by steeping in an ash-lye too weak to act upon the animal fibres. They are then rinsed, fulled for a longer or shorter time according to their nature, and fermented in a proper steep, after having been washed in hot water. They are taken out at the end of a week, but they may be steeped a second time if deemed necessary, to open their pores. They are now cleaned by working them at the horse on both the flesh and grain sides.

A paste is next composed, for 200 skins, of 38 lbs. of rye-flour, which is set to ferment with leaven. This dough is worked up with a sufficient quantity of water to form a bath for the skins, in which they are soaked for 48 hours; they are then transferred into small tubs, where they remain during fifteen days, after which they are washed at the river. These operations serve to prepare the skins for absorbing the astringent juices with uniformity. A decoction of willow-bark (*Salix cinerea* and *Salix caprea*) being made, the skins are immersed in the boiler whenever the temperature of the liquor is sufficiently lowered not to injure the animal fibres, and handled and pressed for half an hour. This manipulation is repeated twice daily during the period of a week. The tanning infusion is then renewed, and applied to the same skins for another week; after which, being exposed to the air to dry, they are ready for being dyed, and then curried with the empyreumatic oil of the bark of the birch tree. To this substance the Russia leather owes its peculiarities. Many modes have been prescribed for preparing it; but the following is the one practised in Russia.

The whitish membranous epidermis of the birch, stripped of all woody parts, is introduced into an iron boiler, which, when stuffed full, is covered tight with a vaulted iron lid, having a pipe rising from its centre. A second boiler into which this pipe passes without reaching its bottom, is set over the first, and is luted to it at the edges, after the two are bolted together. They are then inverted, so that the upper one contains the birch-bark. The under half of this apparatus is sunk in the earth, the surface of the upper boiler is coated over with a clay lute, then surrounded with a fire of wood, and exposed to a red heat, till the distillation be completed. This operation, though rude in appearance, and wasteful of wood, answers its purpose perfectly well. The iron cylinder apparatus used in Britain for distilling wood-vinegar would, however, be much more convenient and productive. When the above bodies are unluted, there is found in the upper one a very light powder of charcoal, and in the under one, which served as a receiver, there is an oily, brown, empyreumatic fluid, of a very strong smell, which is mixed with the tar, and which floats over a small quantity of crude vinegar. The former matter is the oil employed to impregnate the skins, by working it into the flesh side with the currier's tools. It is difficult to make this oil penetrate with uniformity; and the Russians do not always succeed in this process, for they turn out many skins in a spotted state. This oil is at present obtained in France by distilling the birch-bark in copper stills, and condensing the products by means of a pipe plunged in cold water. About 60 per cent. of the weight of the bark is extracted.

The skins imbibe this oil most equally before they are fully dry. Care must be taken not to apply too much of it, for fear of its passing through and staining the grain side of the leather. Chevreul has investigated the chemical nature of this odoriferous substance, and finding it to be a peculiar compound, has called it *betuline.*

In the Franklin Institute for February 1843, Mr. Gideon Lee has published some judicious observations on the process of tanning. He believes that much of the original gelatine of the hides is never combined with the tannin, but is wasted; for he thinks that 100 lbs. of perfectly dry hide, when cleaned from extraneous matter, should, on chemical principles, afford at least 180 lbs. of leather. The usual preparation of the hide for tanning he believes to be a wasteful process. In the liming and bating, or the unhairing and the cleansing, the general plan is first to steep the hides in milk of lime for one, two, or three weeks, according to the weather and texture of the skin, until the hair and epidermis be so loosened as to be readily removed by rubbing down, by means of a knife, upon a beam or block. Another mode is to suspend the hides in a close chamber, heated slightly by a smouldering fire, till the epidermis gets loosened by incipient putrefaction. A third process, called sweating, used in Germany, consists in laying the hides in a pack or pile, covered with tan, to promote fermentative heat, and to loosen the epidermis and hairs. These plans, especially the two latter, are apt to injure the quality of the hides.

The *bate* consists in steeping the haired hides in a solution of pigeons' dung, containing, Mr. Lee says, muriate of ammonia, muriate of soda, &c.; but most probably phosphates of ammonia and lime, with urate of ammonia, and very fermentable animal matter. The dry hides are often subjected first of all to the operation of the fulling-stocks, which opens the pores, but at the same time prepares them for the action of the liming and bate; as also for the introduction of the tanning matter. When the fulling is too violent, the leather is apt to be too limber and thin. Mr. Lee conceives that the liming is injurious, by carrying off more or less of the gelatine and albumen of the skin. High-limed leather is loose, weighs light, and wears out quickly. The subsequent fermentation in the bating aggravates that evil. Another process has therefore been adopted in New York, Maine, New Hampshire, and some parts of Philadelphia, called, but incorrectly, *cool sweating*, which consists in suspending the hides in a subterranean vault, at a temperature of 50° F., kept perfectly damp, by the trickling of cold spring-water from points in the roof. The hides being first soaked, are suspended in this vault from 6 to 12 days, when the hair is well loosened, by the mere softening effect of moisture, without fermentation.—H.M.

LEATHER, MOROCCO. (*Maroquin*, Fr.; *Saffian*, Ger.) Morocco leather of the finer quality is made from goat-skins tanned with sumach; inferior morocco leather (roan) from sheep-skins. The goat-skins as imported are covered with hair; to remove which they are soaked in water for a certain time, and they are then subjected to the operation called breaking, which consists in scraping them clean and smooth on the flesh side, and they are next steeped in lime-pits (milk of lime) for several days, during which period they are *drawn out*, with a hook, from time to time, laid on the side of the pit to drain, and replunged alternately, adding occasionally a little lime, whereby they are eventually deprived of their hair. When this has become sufficiently loose, the skins are taken out one by one, laid on convex beams, the work-benches, which stand in an inclined position, resting on a stool at their upper end, at a height convenient for the workman's breast, who scrapes off the hair with a concave steel blade or knife, having a handle at each end. When unhaired, the skins are once more soaked in milk of lime for a few days, and then scraped on the flesh side to render it very even. For removing the lime which obstructs their pores, and would impede the tanning process, as well as to open these pores, the skins are steeped in a warm semi-putrid alkaline liquor, made with pigeons' and hens' dung diffused in water. Probably some very weak acid, such as fermented bran-water, would answer as well, and not be so offensive to the workmen. (In Germany the skins are first washed in a barrel by a revolving axle and discs.) They are again scraped, and then sewed into bags, the grain outermost, like bladders, leaving a small orifice, into which the neck of a funnel is inserted, and through which is poured a certain quantity of a strong infusion of the sumach; and they are now rendered tight round the orifices, after being filled out with air, like a blown bladder. A parcel of these inflated skins are thrown into a very large tub, containing a weaker infusion of sumach, where they are rolled about in the midst of the liquor, to cause the infusion within to act upon their whole surface, as well as to expose their outsides uniformly to the tanning action of the bath. After a while these bladder-skins are taken out of the bath, and piled over each other upon a wooden rack, whereby they undergo such pressure as to force the enclosed infusion to penetrate through their pores, and to bring the tannin of the sumach into intimate contact, and to form a chemical combination with the skin fibres. The tanning is completed by a repetition of the process of introducing some infusion or decoction into them, blowing them up, and floating them with agitation in the bath. In this way goat-skins may be well tanned in the course of one day.

The bags are next undone by removing the sewing, the tanned skins are scraped as before on the curriers' bench, and hung up in the drying loft or shed; they are said now to be 'in the crust.' They are again moistened and smoothed with a rubbing tool before being subjected to the dyeing operations, in which two skins are applied face to face to confine the dye to one of their surfaces only, for the sake of economising the dyeing materials, which may be of several different colours. The dyed skins are grained by being strongly rubbed with a ball of box wood, finely grooved on its surface.

Preparatory to being dyed, each skin is sewed together edgewise, with the grain on the outside, and it is then mordanted either with a solution of tin, or with alum-water. The colour is given by cochineal, of which from 10 to 12 ounces are required for a dozen of skins. The cochineal being boiled in water along with a little tartar or alum for a few minutes, forms a red liquor, which is filtered through a linen cloth, and put into a clean cask. The skins are immersed in this bath, and agitated in it for about half an hour; they are taken out and beaten, and then subjected to a second immersion in the cochineal bath. After being thus dyed, they are rinsed and tanned with Sicilian sumach, at the rate of two pounds for a skin of moderate size. The process is performed in a large tub made of white wood, in the liquor of which the skins are floated like so many bladders, and moved about by manual labour during four hours. They are then taken out, drained, and again subjected to the tanning liquor; the whole process requiring a space of twenty-four hours. The skins are now unstitched, rinsed, fulled with beetles, drained, rubbed hard with a copper blade, and lastly hung up to dry.

Some manufacturers brighten the colour by applying to the surface of the skins, in a damp state, a solution of carmine in ammonia with a sponge; others apply a decoction of saffron to enliven the scarlet tint. At Paris, the morocco leather is tanned by agitation with a decoction of sumach in large casks made to revolve upon a horizontal axis, like a barrel churn. White galls are sometimes substituted for sumach; a pound being used for a skin. The skins must be finally cleaned with the utmost care.

The black dye is given by applying with the brush a solution of red acetate of iron to the grain side. Blue is communicated by the common cold indigo vat; violet, with a light blue followed by cochineal red; green, by Saxon blue followed by a yellow dye, usually made with the chopped roots of the barberry. This plant serves also for yellows. To dye olive, the skins are first passed through a weak solution of green vitriol, and then through the decoction of barberry root, containing a little Saxon blue. Puce colour is communicated by logwood with a little alum; which may be modified by the addition of a little Brazil wood. In all these cases, whenever the skins are dyed, they should be rinsed, wrung, or rather drained, stretched upon a table, then besmeared on the grain side with a film of linseed oil applied by means of a sponge, in order to promote their glossiness when curried, and to prevent them becoming horny by too rapid drying.

The last process in preparing morocco leather is the currying, which brings out the lustre, and restores the original suppleness. This operation is practised in different manners, according to the purpose the skins are to serve. For pocket-books, portfolios, and case-making in general, they must be thinned as much as possible upon the flesh side, moistened slightly, then stretched upon the table, to smooth them; dried again, moistened, and lastly passed two or three times through the cylinder press in different directions, to produce the crossing of the grain. The skins intended for the shoemaker, the saddler, the bookbinder, &c., require more pliancy, and must be differently curried. After being thinned, they are glazed with a polisher while still moist, and a grain is formed upon the flesh side with the roughened lead plate or grainer of the curriers, called in French *pommelle*; they are glazed anew to remove the roughness produced by the pommel, and finally grained on the flesh side with a surface of cork applied under a pommel of white wood.

Tawing of Skins. (*Mégisserie*, Fr.; *Weissgerberei*, Ger.) The kid-, sheep-, and lamb-skins, are cleaned as has been already described. In some factories they receive the tanning power of the submuriate of alumina (from a solution of alum and common salt) in a large barrel-churn apparatus, in which they are subjected to violent agitation, and thereby take the *aluming* in the course of a few minutes. In other cases, where the yolks of eggs are added to the above solution, the mixture, with the skins, is put into a large tub, and the whole trampled strongly by the naked feet of the operator, till the emulsion of the egg be forced into the pores of the skin. The tawed skins, when dry, are 'staked,' that is stretched, scraped, and smoothed by friction against the blunt edge of a semi-circular knife, fixed to the top of a short beam of wood set upright. The workman holding the extremities of the skin with both hands, pulls it in all directions forcibly, but skilfully, against the smoothing 'stake.'

In an entertaining article on tanning in the 11th vol. of the 'Penny Magazine,' at page 215, the following description is given of one of the great tawing establishments of London:—

'In the production of "imitation" kid leather, the skin of lambs is employed; and for this purpose lamb-skins are imported from the shores of the Mediterranean. They are imported with the wool yet on them; and as this wool is valuable, the leather manufacturer removes this before the operations on the pelt commence. The wool is of a quality that would be greatly injured by the contact of lime, and therefore a kind of natural fermentation is brought about as a means of loosening the wool from the pelt.' The following is a description of one of the buildings: 'On the ground floor, a flight of stone steps leads down to a range of subterranean vaults or close rooms, into which the lamb-skins are introduced in a wet state, after having been steeped in water, 'broken' on the flesh side, and drained. The temperature of these rooms is nearly the same all the year round, a result obtained by having them excluded as much as possible from the variations of the external atmosphere; and the result is, that the skins undergo a kind of putrefactive or fermenting process, by which the wool becomes loosened from the pelt. During this chemical change ammonia is evolved in great abundance; the odour is strong and disagreeable; a lighted candle, if introduced, would be instantly extinguished, and injurious effects would be perceived by a person remaining long in one of the rooms. Each room is about ten feet square, and is provided with nails and bars whereon to hang the lamb-skins.

The doors from all the rooms open into one common passage or vault, and are kept close, except when the skins are inspected. It is a point of much nicety to determine when the fermentation has proceeded to such an extent as to loosen the wool from the pelt; for if it be allowed to proceed beyond that stage, the pelt itself would become injured.

When the fermentation is completed, generally in about five days, the skins are removed to a beam, and there 'slimed,' that is, scraped on the flesh side, to remove a slimy substance which exudes from the pores. The wool is then taken off, cleaned, and sold to the hatters, for making the bodies of common hats. The stripped pelts are steeped in lime-water for about a week, to kill the grease; and are next 'fleshed on the beam.' After being placed in a 'drench,' or a solution of sour bran for some days to remove the lime and open the pores, the skins are alumed, and subjected to nearly the same processes as the true kid-skins. These Mediterranean lamb-skins do not in general measure more than about 20 inches by 12; and each one furnishes leather for two pairs of small gloves. These kinds of leather generally leave the leather-dresser in a white state; but undergo a process of dyeing, softening, 'stroking,' &c., before being cut up into gloves.

The tanning of one average-sized skin requires about 1¼ lb. of good Sicilian sumach; but for leather which is to receive a bright scarlet dye, from one half to three quarters of a pound of gall-nuts are employed in preference. Inferior goat-skins are tanned with a willow-bark infusion, in pits, in which they are turned repeatedly, and laid out to drain, as in tanning sole leather. The finest skins for the brightest scarlet are cured with salt, to prevent their receiving damage in the transport, and are dyed before being tanned. This method is practised in Germany and France.

Leather of deer- and sheep-skins is prepared with oil, for the purpose of making breeches, &c., and for wash-leather, used in cleaning plate. After they are completely washed, limed, and beamed, as above described, they have their 'grain' surface removed, to give them greater softness and pliability. This removal of the grain is called 'frizing,' and it is done either with the round edge of a blunt knife, or with pumice-stone. After being freed from the lime by steeping in fermented bran-water, they are pressed as dry as may be, and are then impregnated with cod-oil, by beating with stocks in the trough of a kind of fulling mill. Previously to the application of the oil, they are usually beat for some time alone to open their substance. The oiled skins are stretched, hung up for some time in the air, then fulled with oil as before—a process which is 8 or 9 times repeated. The oil is slowly and evenly poured upon the skins in the trough during the action of the beaters. One hundred skins usually take up in this way from two to three gallons of oil. The fulled oil skins are thrown into large tubs, and left for some time to ferment, and thereby to combine more intimately with the oil. They are lastly subjected to a weak potash-lye-bath, to strip them of the loosely adhering oil. They are then hung up in the air to dry, and dressed for the market.—H.M.

LEATHER, RUSSIAN, *as tanned at Kazan.* The hides to be tanned may be either fresh from the animal or dry, no matter which; they are first laid to soak for three days and nights in a solution of potash, to which some quicklime is added. The potash used is made of the tree called in Russ *ilim* (the common elm), which sort is said to be preferable to any other, if not essential; it is not purified, so that it is of a brown colour and of an earthy appearance: about 12 poods of this (the pood is 36 lbs. English), and 2 poods of lime, serve for 100 skins. As they have no way of ascertaining the degree of causticity of the alkali but by its effect upon the tongue, when they find it weak they let the skins lie longer in the solution.

When the skins are taken out of this solution they are carried to the river, and left under water for a day and night.

Next a vedro of dog's dung is boiled in as much water as is enough to soak 50 skins, (the vedro is equal to 2·696 English imperial gallons) but in the winter time, when the dung is frozen, twice that quantity is found necessary. The skins are put into this solution, not while it is boiling hot, but when at the heat which the hand can bear; in this they lie one day and one night.

The skins are then sewed up so as to leave no hole; in short, so as to be water-tight; about one third of what the skin will contain is then filled up with the leaves and small twigs chopped together of the plant called in Russ Toloknanka (*Arbutus uva-ursi*, sometimes called bearberry), which is brought from the environs of Solikamskaga, and the skin is then filled up with water.

The skins thus filled are laid one on the other in a large trough, and heavy stones upon them, so as by their weight to press the infusion through the pores of the skin in about 4 hours; yet, as it was said at the same time, that the skins are filled up with the same water which had been pressed out 10 times successively, and that the whole operation takes but one day and one night, this leaves but 2½ hours for each time.

The skins are then taken to the river and washed, and are ready for the dyeing. The whitest skins are laid aside for the red and yellow leather.

To soften the skins after dyeing, they are harassed by a knife, the point of which is curved upwards.—H. M.

LEATHER, CURRYING OF. The currier's shop has no resemblance to the premises of the tanner, the tools and manipulations being quite different.

Within the last twenty or thirty years, many tanners have added the currying business to their establishments, and many curriers have likewise commenced tanning; but in each case, an extension of premises is necessary, and the two departments are still separate, The advantages derivable from this arrangement are two-fold:—first, a saving of time is effected, for as the tanned leather is sold by weight, it is required to be well dried before being disposed of to the currier, an operation which is not needed where the tanner carries on the currying also; and secondly, by the currier's art, the skins can be reduced to a comparatively uniform thickness previous to their being tanned, thus saving *time* and *bark* (used for tanning), and insuring a more equal distribution of tannin through the substance of the skin. In the following description, the business of currying will be considered as practised at the present time.

The currier's shop or premises, to be convenient, should be spacious. A frequent, though not universal method, is to have the ground-floor appropriated to such operations as require the use of a large quantity of water. The place or apartment thus used, is called the *scouring-house*, and is commonly furnished with a number of *vats* or *casks open at one end*, in which the leather is placed for the purpose of soaking, and undergoing such treatment as will be hereafter described. In this apartment also is placed a large, flat, slate stone, called a *scouring stone*, or, more consistently, the stone on which the leather is scoured. This stone, which has its face perfectly flat and smooth, and which should measure 8 or 9 feet in length, by 4½ broad, forms a table, supported generally by masonry, but sometimes by a strong frame of wood, so constructed that the water, which is freely used in scouring, may drain off on the opposite side from that on which the workman is engaged; an inclination of about 3 or 4 inches on the width of the table, is sufficient for this purpose. Another piece of furniture very frequently found *in*, or *on the same floor with* the scouring-house, is a block of sandstone, in the form of a parallelopipedon, between 2 and 3 feet long, and 9 or 10 inches broad, the upper face of which is kept as near as possible a perfect plane; this stone is fixed at a convenient height on a strong trussel, and is called the *rub-stone*, because here the workman *rubs* or sharpens his knives and other tools. In some large establishments where the premises and water are heated by steam, the scouring-house will be found with a service of pipe leading to the various vats, and the boiler for generating the steam may be conveniently placed in or near this part of the building.

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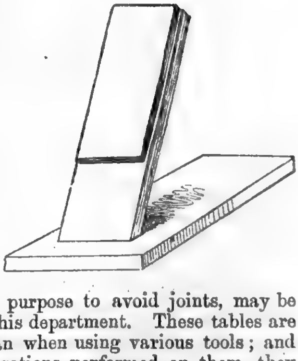

The floor above the scouring-house, in the arrangement here laid down, is what is specially designated *the shop*. The furniture in this department consists of a *beam* (*fig.* 1364), on which the leather is *shaved*. It consists of a heavy block of wood, on which the workman stands, and into one end of which a stiff piece of wood is firmly mortised, at an angle of about 85°; this upright (so called) is about a foot wide, the height being greater or less, according to the height of the workman, each of whom has his beam adjusted to meet his convenience. On the front of the *upright* a piece of deal is firmly screwed, to which is glued a face or plate of *lignum vitæ*, worked to perfect smoothness to agree with the edge of the knife used in the operation of shaving. It is of the greatest importance to the workman, to keep his *skin* from injury, that this knife and beam should be kept in good order. A *table* or *tables*, generally of mahogany, large planks of which are used for the purpose to avoid joints, may be said to form a necessary part of the furniture of this department. These tables are firmly fixed, to resist the pressure of the workman when using various tools; and as light is of the greatest consequence in the operations performed on them, they are usually placed so as to have windows in front of them. A high *trussel* is frequently used, across which the leather is thrown, after undergoing any of the processes, while the currier subjects other pieces to the same operation.

Another part of the premises is termed the *drying-loft*. In good buildings the drying-loft is surrounded with *weather-boards*, constructed to be opened or closed as may be required. The use of this part being the drying of the leather, the ceiling is furnished with a number of rails or long pieces of wood, with hooks or nails on which to hang the leather for drying; and where steam is used for this purpose, the floor is traversed with pipes for heating the *loft*. Here also is a table, similar to that previously described; it should not be less than 7 or 8 feet long by 4½ broad, if possible, without joint, and with a smooth face.

There are other subordinate departments, each furnished with a *table* similar to those described.

Of the tools used in currying, the *knife* stands first in importance (*fig.* 1365). Here *a* and *b* are two handles, *a* is held in the left hand, and forms a powerful lever when the edge *c* is applied to the leather. The blade of the currier's knife is peculiarly *tempered*; it is composed of a plate of fine steel, strongly riveted between two plates of iron. This instrument is taken to the *rub-stone*, and ground to a perfectly sharp edge by successively rubbing forward and backward; care being taken to keep the edge *true*, that is, *straight*. When this has been satisfactorily accomplished, it is still further rubbed on a fine Scotch or Welsh stone, called a *clearing-stone*, until the scratches of the *rub-stone* disappear.

In this operation a fine thread or *wire* forms on the edges, for the knife has two edges, *c*, *c*, which must be carefully got rid of; after which it is wiped dry, and the edges greased with tallow or oil. The workman then takes a strong steel, and placing himself on his knees, he fixes the knife with the straight handle *b* against any firm body, and the cross handle *a* between his knees; then holding the steel in both hands, he carefully rubs it forward and backward the whole length of the edge. During this operation the knife is gradually raised by means of the handle *a*, until it is nearly perpendicular; by this means the edge is turned completely over. If the knife is not well tempered, the edge thus obtained will be irregular or broken; in either of which cases, it is of no use whatever.

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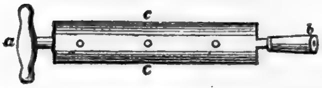

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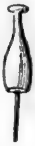

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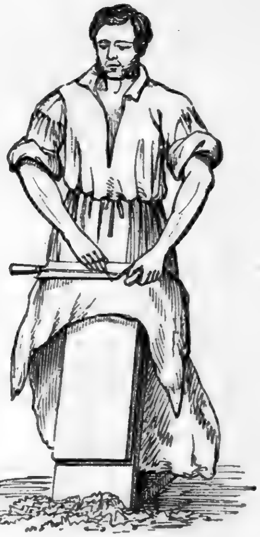

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To keep the instrument just described in proper order requires great skill on the part of the currier. The edge is so delicate and liable to injury that it cannot be used more than a minute or two without losing its keenness. To restore this a very carefully prepared small steel is used, *fig.* 1366; the point of the steel is first run along the groove which is formed by turning the edge over, and the steel is then made to pass outside the edge (*fig.* 1367). It is remarkable that a skilful hand can thus restore the efficiency of the knife, and keep it in work for hours without going for a new edge to the *rub-stone*. The other tools will be described as their uses are mentioned.

The first thing done by the currier is the soaking of the leather received from the tanner in water; the skin requires a thorough wetting, but not to saturation. In some cases the thicker parts are partially soaked before the immersion of the whole, and when, from the nature of the skin, this cannot be done, water is applied to the stout parts after the dipping; it is requisite that the whole should be as nearly as possible equally wet. In some instances the wetted leather is beaten, and sometimes a coarse graining-board (hereafter to be described) is used, to make it more supple previous to shaving it. The skin is then laid over the beam (*fig.* 1368), and the rough fleshy portion is shaved off. This operation is generally called *skiving*. In all the operations at the *beam* the leather is kept in its place by pressure of the knees or body of the workman from behind. In *skiving* the right-hand handle of the knife somewhat precedes the left, but in *shaving*, properly so called, the left-hand precedes the right, *fig.* 1369. In *skiving* the knife is driven obliquely a few inches at a time; in *shaving* it is driven with great force, not unfrequently from the top to the bottom of the beam; great skill is requisite in the performance of these operations, to guide the knife and to keep its edge. The carpenter's plane can be most completely regulated by the projection of the plane iron from the wood, but the currier's knife admits of no such arrangement, and the unskilful currier is constantly liable to injure the leather by cutting through it, as well as by failing to produce a regular substance. The kind of skin, and the use for which it is designed, will regulate the work at the beam. In some cases, as in the calf-skin, it is skived and then shaved, or, as it is called, *flattened* at right angles to the skiving—in other kinds, as the cow-hide prepared for the upper leather of heavy shoes, after skiving it is *shaved across* (*i. e.* nearly at right angles to the skiving), and *flattened* by being again shaved in the same direction as the skiving. In some manufactories there are certain kinds of leather which are subjected to the operation called by curriers *stoning* before *flattening*: this is done by forcibly driving the stock-stone (*fig.* 1370) over the *grain* side of the leather, thereby stretching it, and rendering the grain smooth. The *flattening* process is considerably facilitated by this stoning; and if the skin has been allowed slightly to harden by exposure to air, and the edge of the knife is fine, as it should be, the workman has but to strike the flat part of the knife over the leather after the shaving is performed, to produce a beautiful face to the flesh side of the skin. It will not be difficult to understand that a good hand is easily distinguished from an inferior one in this part of the business. With such nicety will a skilful workman set the edge of his knife, that although there seems nothing to guide him, he can take shaving after shaving from the hide extending from the top to the bottom of the beam, thus rendering the leather extremely even in its substance.

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After the process of shaving is completed, the leather is placed in water, where it remains until it is convenient to carry on the operation next required. It is to be observed that in the condition in which leather is shaved, it cannot long be kept without becoming heated; when, however, it is put into water, it is safe from injury, and may be kept a very long time, provided the water be occasionally changed for a fresh, sweet supply; stale water is regarded as injurious for the skin to remain in.

Scouring is next proceeded with; the skin is taken out of the water, and laid on the scouring-stone. In respectable manufactories, it is usual first to *scour on the flesh*; this is done by passing a *slicker* smartly over the flesh side, by which the *grain* of the leather is brought into close contact with the scouring-stone, and, being in a wet condition, the air is easily excluded, so that the leather *sticks* to the stone. A plentiful supply of water is now applied, and a large brush, with stiff hairs, is rubbed over the flesh, or upper side. Portions of the surface, in a pulpy condition, come off with the scrubbing, and the skin presents a soft, whitened and pulpy appearance; the pores are rendered capable of containing more moisture, and, altogether, the leather is much benefited. The *slicker* is a plate of iron or steel, or for particular purposes, of brass or copper; it is about five inches long, and like the *stock-stone*, is fixed in a stock, or handle (*fig.* 1371). It is sharpened at the *rub-stone*, by grinding the plate perpendicularly, and then on either side, thus producing two edges (or, rather, *right angles*). The edges thus produced are not of an order to cut the leather, but rather to *scrape* it. The *slicker* is not intended to remove irregularities in the leather; but its uses are various, and it may be considered a very important tool, as will hereafter appear.

In the process of *tanning*, the grain side of the hide or skin becomes covered with a whitish body, derived from the bark called *bloom*; this is more or less difficult to remove according to the hardness or softness of the water used in tanning, and the peculiar treatment of the tanner. It is, however, the currier's business to remove it, which he effects thus :—In the case of leather whose grain is *tender*, as *cordovan*, which is manufactured from horse-hides, the grain being kept uppermost, the leather is spread on the scouring-stone, and being plentifully supplied with water, is stretched by using the slicker, or a fine pebble, ground to the shape of the stock-stone, the *bloom* is thus loosened, and at the same time, by making it adhere to the scouring-stone, the next operation is readily carried on, which consists in smartly brushing the grain with a stiff-haired brush, and at the same time keeping a quantity of water on the surface, the slicker is again used to remove the water and loosened *bloom*, and the scouring is complete. In the scouring of calf-skins, and cow- or ox-hides, the stock-stone is used to fix the leather, and a piece of pumice-stone, the face of which has been ground to smoothness, and afterwards cut in grooves, is then forcibly rubbed over the grain, in order to remove the *bloom*. In this, as in other operations on the scouring-stone, *water* is a necessary ingredient. The *bloom* being sufficiently loosened by the pumice-stone, the *brush* is used to scrub up the remaining dirt, which is then removed by the stock-stone or slicker. In harness leather, which is stout, and requires to be stretched as much as possible, the pumice-stone is seldom used, the stock-stone and scouring-brush being lustily applied until the bloom is sufficiently removed. Ordinary manufacturers within the present (nineteenth) century have considered the operations of the *scouring-house* complete at this point. The modern currier takes a different view, and not unfrequently detains his *scoured* property for days, and sometimes for weeks, in the *scouring-house*.

If the leather is imperfectly tanned, or it is required to be made of a bright colour, there are other processes to be passed through. In these cases sumach (an evergreen shrub of the natural order *Anacardiaceæ*, genus *Rhus*, and from the bark of which all the leather made in Turkey is said to be tanned) is infused in boiling water, and when cooled to a tepid state the leather is placed in it. After staying a sufficient time it is taken to the scouring-stone; if *cordovan*, it is slicked as dry as can be well accomplished on the *flesh* side; other leather is for the most part slicked in a similar way on the grain side. Saddle leather, which is required to be of a bright colour, is still further placed in warm water slightly acidulated with sulphuric or oxalic acid, or both; here for a time it is kept in motion, then taken to the scouring-stone, it is washed with peculiar chemical lotions, according to the taste or knowledge of the workman; then again it is dipped in tepid sumach infusion, then slicked with a copper or brass slicker (iron is liable to stain leather thus prepared), and a thin coat of oil being applied to either side, it is removed to the *drying-loft*. Until within a very few years much time and trouble were taken to produce *very bright* leather for the saddler; but of late brown-coloured leather has been adopted to a considerable extent, as it is less liable to become soiled. Nearly all leather is placed a short time in the *loft* before further manipulations are carried on, in order to harden it slightly by drying.

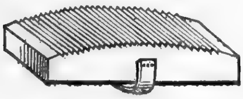
In the drying-loft, or its immediate vicinity, the leather receives the *dubbing* (*daubing*, probably) or *stuffing*. The substance so called is composed of tallow, brought to a soft plastic condition by being melted and mixed with *cod-liver oil*; occasionally *sod* (an oil made in preparing sheep-skins) is, in very small quantities, added to the mixture. This is laid upon the leather either with a soft-haired brush or a mop made generally of rags.

The leather is prepared for stuffing by wetting slightly such parts as have become too dry. It is then taken to the table previously described, which, being slightly oiled, the process is carried on by placing the skin on the table in the manner most convenient for stretching it and making the surface smooth. In those kinds that have a rough wrinkled grain the flesh side is placed next the table, and the *stock-stone* is used very smartly to stretch and smooth the grain. A kind of *clamp* or *holdfast*, composed of two cheeks fastened with a screw, is sometimes used to prevent the leather from moving during this operation, but in general these are not required; the slicker is then applied to remove the marks left by the *stock-stone*, and a thin stuffing being spread over the grain it is turned over, slicked on the flesh lightly, a coat of *stuffing* is spread over it, and it is hung up to dry. In those kinds which have to be blacked (or stained) on the *grain*, a little *cod-oil* only is spread on the grain, and the slicker is applied on the flesh side most laboriously previous to *stuffing*. Much skill is required to give the requisite quantity of *stuff* (dubbing) to the leather without excess, excess being injurious, and the quantity required is further regulated by the freshness or otherwise of the leather, the tan-yard from which it comes, and the treatment it has received in the scouring-house.

When dry, the skins or hides are folded together, to remain until required. It is certain the leather improves by remaining some weeks in this condition. It should be observed that, in drying, the leather absorbs a large quantity of the oleaginous matter with which it is charged, and the unabsorbed portion forms a thick coating of hardened greasy matter on the flesh side.

Leather which has to be blackened on the flesh (*wax-leather*), from this point, receives different treatment from *grain*-leather. *Wax*-leather is taken to the *shop-table* and softened with a *graining-board.* The skin is laid on the table and doubled, grain to grain, the *graining-board* (*fig.* 1373), which is confined to the hand by a leather strap (*a a*), is driven forward and drawn back alternately until a grain is raised on the leather, and it has attained the required suppleness. Observe, the graining-board is slightly rounded on the lower surface, and traversed by parallel grooves from side to side, which are coarser or finer, as occasion requires. The grease is next removed from the flesh by the slicker. and afterwards a sharp slicker is passed over the grain to remove grease or other accumulations from it. The next process is called *whitening.* The leather is laid over the *beam,* and a *knife* with an extremely fine edge is used to take a thin shaving from the flesh side; this is a point at which a currier's skill is tested. The knife used is one that has been very much worn, the quality of which has been tested to the utmost; and so extremely *true* is the edge expected, that not the slightest mark (*scratch*) is allowed to appear on the surface of the leather. Only a good workman can satisfactorily accomplish this. The slightest gravel in the flesh of the skin may break the edge of the knife in pieces, and it is not easy to rectify so serious a misfortune; besides, a poor workman may turn up the edge by *steeling,* an operation which ought to mend the mischief instead of provoking it.

1372



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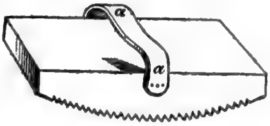


A fine *graining-board* is next used to soften the leather; the stiffer parts being *boarded* both on the grain and flesh sides, and the operation being carried on in two or three directions, to insure both softness and regularity of grain. *Boarding* is performed by doubling the leather and driving the double part forward and drawing it backward by the graining-board.

The leather is now prepared for the *waxer,* and passes, consequently, into his hands. Waxing, in large establishments, is a branch considered separate from the general business, and is usually in the hands of a person who confines himself to this occupation alone. The skin is laid on the table, and the *colour* rubbed into the flesh side with a brush. It is necessary to give the brush a kind of circular motion to insure the required blackness in the leather. The *colour* is made by stirring a quantity of the best lampblack into *cod-liver-oil*; sometimes a little *dubbing* is added, and in order to make it work smoothly so as not to clog the brush, some stale *tan-water* from the vats in the scouring-house is *beaten up* with the mixture until it combines therewith. The preparation of the *colour* is an important affair, and requires a considerable amount of time and labour to render it such as the *waxer* desires.

A *slick-stone,* or *glass,* is next used; this tool is about the size and shape of the slicker, but instead of being ground like it, the edges are very carefully removed, so that while, from end to end, it preserves nearly a right line, it is circular *across* the edge. The *stone* (a fine pebble) is little used now, plate-glass being substituted for it. The use of the tool just described is to smooth the flesh after the operation by the colouring brush, thereby getting rid of any marks made on the surface.

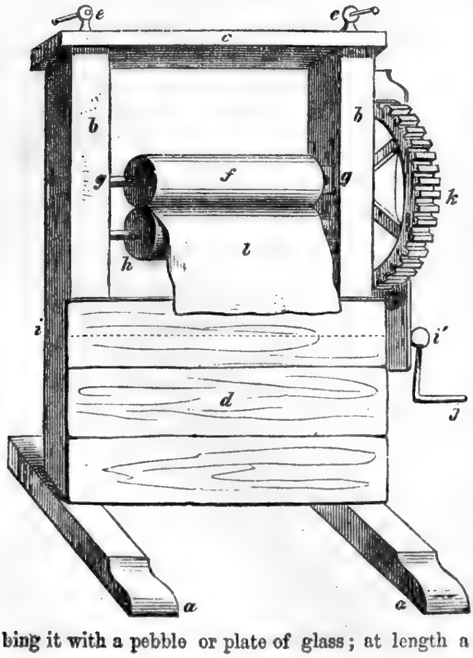
The next step in waxing is what is called *sizing.* Size is prepared by boiling glue in water; the melted glue is diluted with water to the extent required, and in some cases it is softened by mixing *cod-liver oil* with it in cooling. When cold, it is beaten up with various ingredients, according to the taste or experience of the waxer; the waxer then well rubs the size into the coloured side of the leather, and with a sponge, or, more generally, the fleshy part of his hand, smooths it off. When dry, the *slick-stone,* or *glass,* is again applied, thus producing a polish on the size; and a very thin coat of oil completes the work. In different manufactories different methods are pursued, but the above is convenient and satisfactory in almost all circumstances. It is now ready for the shoemaker.

Leather intended to be blacked on the grain is left folded up when dry after stuffing. Some years ago it was the custom to stain these kinds of leather while wet in the scouring-house, by spreading stale urine over it, and then applying a solution of *copperas* (sulphate of iron). That method is now exploded. The dry skins or pieces of leather are laid on the shop-board: a brush is used to saturate the *grain* with urine, or, as is now more common, a *solution of soda in water*, and a peculiar preparation of *iron in solution* is afterwards laid over it, which blackens the surface. It may be observed that in wax-leather a body of black is laid on, and rubbed into the flesh; in grain-leather the black is a stain. After the blackening, it is necessary to rub a small quantity of oil or *dubbing* over the blackened surface, then turning the oiled grain toward the table, a sharp slicker is used on the flesh side; the leather sticks to the table by means of the oil, and the slicker is driven so smartly over it, that it is *stretched* on the table at the same time that the grease is removed. It is quite an important point to take *all the stretch* out of the leather in this operation, after which it is turned over; the table is covered with a very thin coat of hard tallow, a roll of tallow being rubbed over the table, for the purpose of keeping the leather fastened to it. A *dull* slicker is used on the grain to remove remaining marks and wrinkles, or to smooth any coarse appearance on the grain; a sharp slicker removes all the grease, and a thin coat of weak size, made of glue dissolved in water, is spread over it, and the process, usually called *seasoning*, is completed. The next object is carefully to dry the *seasoned* leather, and in this state it may be stored without injury.

The next step is very similar to that described in the case of *wax-leather*, and called whitening:—it is then softened by means of a fine graining-board, or a board of the same shape and size covered with cork, the grain side is placed next the table, and the flesh doubled against the flesh, and thus driven forward and backward until the required degree of suppleness is obtained. The loose particles of flesh are brushed off, and a slicker carefully passed over the grain removes all *marks* of the last operation. If a sufficiency of *stuff* has not been applied in the drying-loft, the deficiency is remedied by a coat of *tallow-dubbing* now spread over the grain, and allowed to remain some hours. As the leather absorbs the oily matter, a hardened coat of grease has to be removed by the aid of the slicker. The leather is then *sized*, and a very thin coat of oil spread over the size, completes the operation.

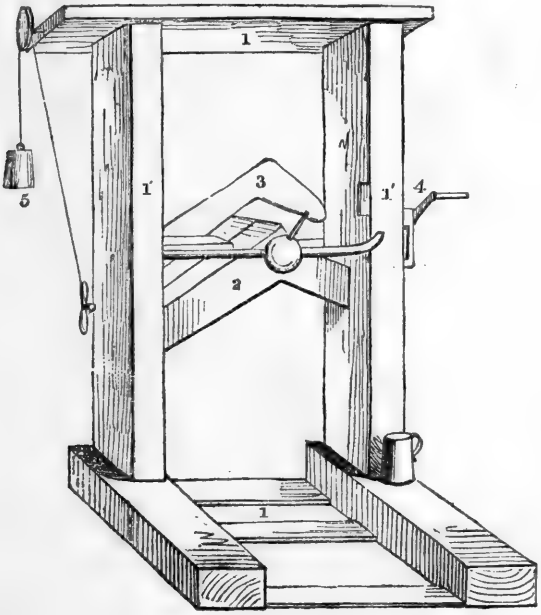
In the preparation of various kinds of leather, or of leather for particular purposes, the currier has particular appliances. *Harness-leather* is considerably dryer than other kinds before stuffing, and is subjected to immense labour by the stock-stone and slicker, to procure a smooth grain. It is blackened when dry like other *grain*-leather, but instead of the oiling and other processes described, the hardest tallow procurable is rubbed into it, *stoned* with a fine pebble, slicked, and tallow again rubbed into it by the hand. When dry after this operation, the grease is slicked from the flesh side, and a repetition of the tallowing, stoning, and rubbing finishes the work.

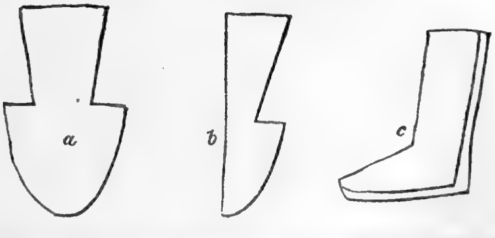
1374



Saddle-leather, which is cut into comparatively small pieces, after hardening in the drying-loft, is passed through a very different process from any described previously. The skin of the hog is much used for certain parts of hackney saddles, and the bristles, when removed by the tanner, leave indentations, or even holes in the tanned skin. Probably it was deemed desirable to obtain some imitation for the parts of the saddle where the hog-skin was not suitable. The skin of the dog-fish (*Scyllium*, Cuv.), to some extent supplied the imitation, having hard tubercles on its surface. At first the skin was laid on the leather, and lustily pressed into it by rubbing it with a pebble or plate of glass; at length a press was invented, and, more recently, various methods have been proposed to produce the best effect. We have here (*fig.* 1374) a representation of one of these presses, which may stand as a type of all others *a a* are the feet into which the uprights are inserted; *b b* are the two upright sides tied at the top by *c*, a similar cross-piece ties them a little above the feet; *d* is a leaf fastened with hinges, which closes upon *c* when the press is not in use; *e e* are screws which press on the iron plate, in which the axes of the roller *f* are inserted; these plates imbedded in the uprights *b b* have considerable play, so as to allow the rollers *f h* more or less pressure as the case may require. The dotted line *i i'*, represents an iron bar or cylinder, supplied with a small cog-wheel at *i'*, and a *crank handle j*; this is turned round by the hand, and the small cog-wheel acts on a larger one, *k*, which is attached to the axis of the roller *f*: *f* is a solid roller of hard wood, such as *lignum vitæ*; upon this cylinder is strongly glued the *fish-skin*, previously alluded to; *h* is a cylindrical solid piece of wood, covered with stout flannel; *l* is a piece of leather on which the leather to be pressed is placed; when all is adjusted, the piece to be pressed is placed on *l*, the handle is moved slowly round, and the whole is carried between the rollers; the leather thus receives the imprint of the *fish-skin*, and at the same time becomes extremely solid. After drying, this is fit for the saddler.

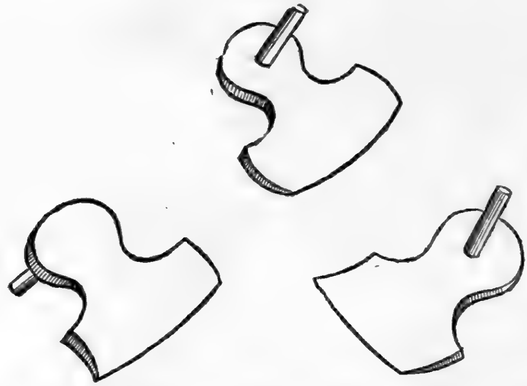
1375



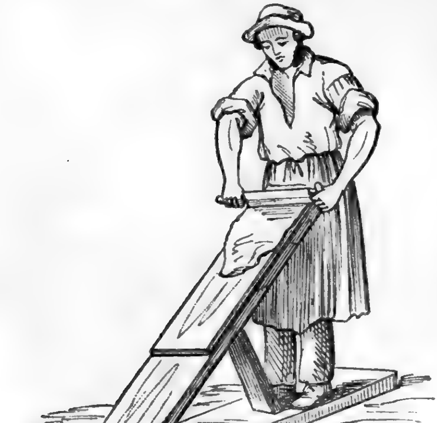


Of late years the currier has undertaken an office which was previously the business of the bootmaker; namely, the *blocking* of boot fronts. This is performed by the instrument represented by *fig.* 1375. The leather is first dressed, as previously described, up to the point of being ready for *whitening*. The fronts are then cut (*fig.* 1375 *a*), and when folded or doubled appear as *fig.* 1375 *b.* 1′ 1′, 1 1, is a strong framework; 2, represents a pair of cheeks, strongly fastened in the frame, and regulated as to *distance* by a screw; these cheeks are lined with zinc; 3 is a strong plate of metal, the angle at 3 corresponding exactly with the angle of the cheeks; the ends of this plate are fixed in moveable plates passing down the columns 1′ 1′; 4 is a handle by which the instrument is worked, and which, by cog-wheels acting on the moveable plates, brings 3 downwards. The *front, a,* is laid, after a thorough soaking in water, over the cheeks 2, the handle being turned, 3 comes down upon the front, and forces it through the small opening between the cheeks, and when brought out below the cheeks, it has the appearance given in *fig.* 1375 *c.* The plate 3 having carried the front between the cheeks, is removed (*below*), and the weight 5 assists in bringing the perpendicular moveable plates to their place, when 3 is again put in position; and thus the operation is rapidly carried on. After this, the *fronts* are regularly placed on a *block*, being forced into position by an instrument called the *flounder* (*fig.* 1376), and *tacked* to their place; after this, they are slightly oiled and dried. Some ingenious methods have been adopted for softening the fronts, so as not to disturb the *blocking*. They are whitened on a very sloping *beam* (*fig.* 1377), which enables the workman to hold them better than he could on the common beam. They are again *blocked* by the *waxer*, and when these processes are carefully performed, much trouble is saved to the bootmaker. Of course, in a manufactory many appliances are found which are not here mentioned; the general idea, however, may be easily gathered from this description. The work is dirty and very laborious, requiring great skill and experience, and consequently good workmen have generally commanded better wages than other mechanics.

1376



1377

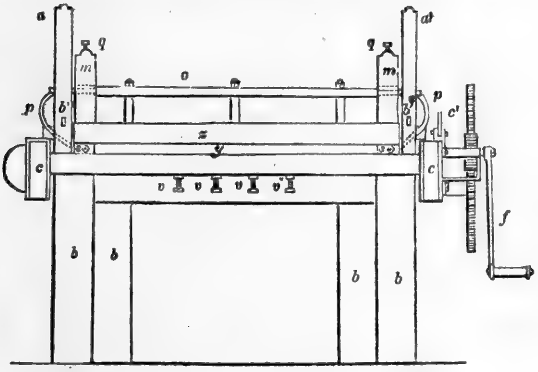


Hides intended for covering coaches are shaved as thin as shoe hides, and blacked on the grain.—H. M.

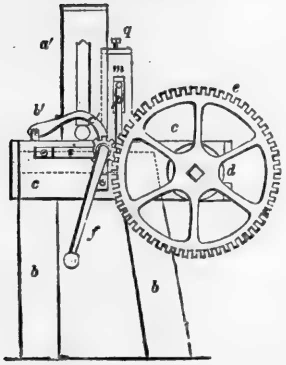
LEATHER SPLITTING. This operation is employed sometimes upon certain sorts of leather for glovers, for bookbinders, sheath-makers, and always to give a uniform thickness to the leather destined for the cotton and wool card-makers.

Figs. 1378, 1379, 1380, 1381 represent a well-contrived machine for that purpose; of which *fig.* 1378 shows the front view, *fig.* 1379 a view from the left side, *fig.* 1380 a vertical section across the machine, and *fig.* 1381 a ground plan. *a* is a strong table, furnished with four legs *b*, which to the right and left hand bears two horizontal pieces *c*. Each of these pieces is cut out in front, so as to form in its substance a half-round fork, that receives a cylinder *d*, carrying on its end a toothed spur-wheel *e*. Motion is communicated to the wheel by means of the handle *f*, upon whose axis the pinion *i* is fixed, working into the wheel *d*, made fast to the end of the cylinder round which the leather is rolled. The leather is fixed at one of its ends or edges to the cylinder, either with a wedge pressed into a groove, or by a moveable segment of the cylinder itself.

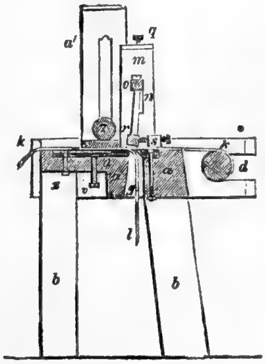
1378



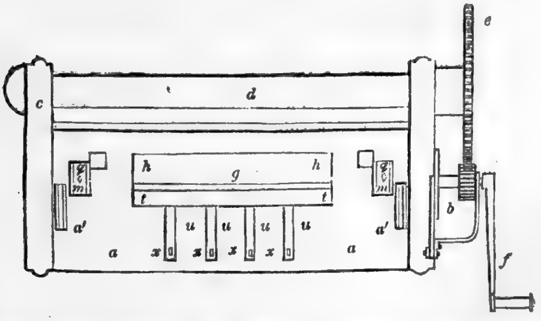
1379



1380



1381



The table, *a*, is cut out lengthwise with a slot, that is widened below, as shown in *fig.* 1380.

The knife *h* (*figs.* 1380 and 1381) is fixed flat upon the table with screw bolts, whose heads are countersunk into the table, and secured with taps beneath (*fig.* 1380), the edge of the knife being placed horizontally over the opening, and parallel with it.

In *fig.* 1380 the leather, *k*, is shown advancing against the knife, getting split, and has a portion coiled round the cylinder, which is made to revolve in proportion as the leather is cleft. The upper portion of the leather is rolled upon the cylinder *d*, while the under half, *l*, falls through the oblong opening upon the ground.

In regulating the thickness of the split leather, the two supports, *m*, act; they are made fast to the table *a* (one on each side of the knife), and are mortised into the table by two tenons secured beneath. These supports are furnished near their tops with keyed slots, by means of which the horizontal iron rod *o* (*figs.* 1378, 1380) is secured, and outside of the uprights they press upon the springs *p p*, which tend to raise the rod, *o*, in its two end slots; but the adjusting screws *q*, which pass down through the tops of the supports into the mortise *n* (*fig.* 1380), and press upon the upper half of the divided tenon, counteract the springs, and accordingly keep the rod *o* exactly at any desired height or level. The iron rod *o* carries another iron bar, *r*, beneath it, parallel and also rectangular, *fig.* 1380. This lower bar, which is rounded at its under face, lies upon and presses the leather by the action of two screws, which pass through two upright pieces *s* (*figs.* 1378 and 1380) made fast to the table; thus the iron bar *r* may be made to press forwards the edge of the knife, and it may be adjusted in its degree of pressure, according to the desired thickness of the leaf of split leather that passes through under it.

Fig. 1380 shows that the slant or obliquity of the knife is directed downwards, over one of the edges of the oblong opening *g*; the other edge of this opening is provided with an iron plate *t* (*figs.* 1378, 1380), which serves to guide the blade in cutting the leather to the proper depth. For this purpose the plate is made adjustible by means of the four springs *u* (*fig.* 1381) let into the table, which press it downwards. Four screws, *v*, pass down through the table, each belonging to its respective spring *u*, and by means of these screws the plate *t* may be raised in any desired degree. Each of the screws *u* has besides a small rectangular notch through which a screw bolt *x* passes, by which the spring is made fast to the table. Thus also the plate *t* may be made to approach to or recede from the knife.

y, in *figs.* 1378 and 1380, is a flat board, laid upon the leather a little behind the edge of the plate *t*; this board is pressed by the cylinder *z*, that lies upon it, and whose tenons rest in mortises cut out in the two supports *a′*. The cylinder *z* is held in its position by a wedge or pin, *b* (*figs.* 1378 and 1380), which passes through the supports. When the leather has been split, these pins are removed, and the cylinder rises then by means of two counter-weights, not shown in the figures.

The operation of the machine is as follows:—The edge or end of the leather being secured to the cylinder *d*, the leather itself having the direction upon the table shown in *fig.* 1380, and the bar *r* its proper position over the knife, the edge begins to enter in this position into the leather, while the cylinder *d* is moved by the handle or winch, and the piece gets split betwixt the blade and the roller *d*. When the other end of the leather, *k*, advances to the knife, there is, consequently, one half of the leather split; the skin is to be then rolled off the cylinder *d*; it is turned; the already split half, or the end of the leather, *k*, is made fast into the wood of the cylinder, and the other half is next split; while the knife now acts from below, in an opposite direction to what it did at first.

That the unrolling of the leather from the cylinder, *d*, may not be obstructed by the pinion *i*, the stop-wedge *e* (*figs.* 1378, 1379) is removed from the teeth. In the process of splitting, the grain side of the leather is uppermost, and is therefore cut of an uniform thickness, but the under side varies in thickness with the inequality of the skin.

Several other ingenious contrivances have been introduced for this purpose, illustrated descriptions of which have been given by Hebert, who states that a splitting-machine, long used by the Messrs. Bevington, of Bermondsey, had been made to split sheep-skins into three equal parts, one of which, that on the grain side, might be used as leather; the middle portion converted into parchment; and the slice on the flesh side, being unequal in thickness, and therefore unfit for any better use, being used for glue-making. In this machine the skin is drawn between two revolving rollers, and presented, as it emerges from their grasp, to the edge of a long and very sharp knife, which is kept continually moving a little backwards and forwards with great velocity. As a skin of unequal thickness could not be grasped in the proper manner between two perfectly true and rigid rollers, the upper roller, instead of being solid, is composed of a number of circular discs or rings of metal, about half an inch thick, slipped on to an axis rather smaller than the holes in their centres, but compelled to revolve with it by means of what may be termed a planetary axis, which is a rod passing loosely through holes in the whole series of discs between their centre and their circumference, and so connected with the axis by its ends as to be carried round with it. By this contrivance the upper roller is enabled to adapt its surface to that of the skin, which is everywhere pressed with an equal force, due to the weight of the discs of which the upper roller is composed. It is stated in the 'Penny Magazine' 'that this machine will split a sheep-skin of the ordinary size in about two minutes, during which time the knife makes from two to three thousand vibratory motions to and fro.' This machine is said to be the invention of Lieutenant Parr. Another contrivance is known as Duxbury's Patent Skin-Splitting Machine, in which the knife consists of a series of plates of steel, so attached to the periphery of a wheel or disc, seventeen feet in diameter, as to form a gigantic cutting instrument, resembling a crown or trepan saw, the compound blade projecting horizontally from the rim of the wheel parallel to its axis. The skin to be split passes round the circumference of a horizontal drum, the axis of which is at right angles with that of the great disc, and lies very nearly in the same plane with its face, and which instead of being perfectly cylindrical has its sides so hollowed as to present a concavity perfectly tallying with the curvature of the periphery of the disc. As therefore the drum revolves it brings the skin, which is confined closely to its concave surface by a contrivance somewhat resembling the upper roller in the machine above described, in contact with the edge of the revolving knife, which cuts by a continuous onward movement, instead of a sawing action backwards and forwards. The extreme nicety required to fix the concavity of the feeding roller to the edge of the circular knife, and to keep the knife or cutter itself perfectly true in shape, appear to be the chief objections to this ingenious contrivance.—*Penny Cyclopædia, Suppl.*, '*Leather.*'

Exports of leather of British produce and manufacture in 1872:—

		Total value
Tanned, unwrought	139,019 cwts.	£1,220,981
Wrought, boots and shoes	579,130 dozen pairs	1,695,248
Other articles unenumerated	1,937,604 lbs.	376,441

Imports of Leather in 1872.

		Total value
Leather, unwrought: hides not tanned, tawed, curried, or in any way dressed	808,930 cwts.	£3,063,920
Hides, wet	627,930 „	1,915,342
„ tanned, not otherwise dressed	23,574,061 lbs.	1,179,716
„ tanned, curried, but not enamelled	3,135,162 „	479,680
„ varnished, japanned, or enamelled	479,658 „	123,098

Imports of leather manufactured, &c., in 1872:—

		Value
Boots and shoes	46,139 dozen pairs	£151,218
Gloves	1,052,717 „	1,403,622
Unenumerated	— „	139,209

LEATHER-CLOTH. Under the name of *American Leather-cloth*, an enamelled oil-cloth has been introduced. Much of it possessed great elasticity, and resembled the vegetable leather described in the next article. The trade has, however, rapidly declined, as will be seen by the following table of *imports* of this material:—

	yards	value
1854	631,304	£38,210
1855	565,395	42,405
1856	507,326	38,069
1858	174,573	13,094
1860	151,969	11,398
1861	127,051	9,528

The recent importations of leather-cloth are not obtainable.

LEATHER, VEGETABLE. Under this name a new material, composed of india-rubber spread upon linen, has been introduced. Of this the 'Mechanics' Magazine' writes:—'Having seen some specimens of these leathers, as well as various articles of utility manufactured therewith, we have been induced to pay the extensive works of Messrs. Spill and Co., the eminent Government contractors, on Stepney Green, a visit, in order to cull sufficient to place upon record the present position of artificial as a substitute for real leather. The face and general character of the vegetable leather resembles the natural product so closely, that it is only by actual examination that the difference can be determined. This is more particularly the case in that description which is made for bookbinding, the covering of library tables, and like purposes.

Amongst other advantages it possesses over leather proper, may be mentioned, that however thin the imitation is, it will not tear without considerable force is exercised; that it resists all damp, and that moisture may be left upon it for any period without injury, consequently, it does not sodden or cockle, is always dry, and its polish is rather increased than diminished by friction. Add to these facts, that any attempt to scratch or raise its surface with the nail, or by contact with any ordinary substance, will not abrade it, and enough will have been said to justify its entering the list against an article of daily use, which has of late years been deemed far from sufficient for the demand, and has consequently risen in price to the manifest loss and injury of every class of the community. We believe that the largest entire piece of real leather that can be cut from a bullock's hide, is not more than 7 feet by 5 feet, and this includes the stomach and other inferior parts. Vegetable leather, on the contrary, is now produced 50 yards in length and 1½ yard wide, every portion being of equal and of any required thickness, and the smallest portion is convertible. We were agreeably disappointed, however, to find that instead of vegetable leather being a discovery requiring the aid of ourselves and contemporaries, it was, although so young, an active agent in the fabrication of numerous articles of daily requirement, and that it had already become the subject of large, indeed we may say enormous, contracts. Caoutchouc and naphtha are used in its manufacture; but by a process known to the senior of the firm, who is himself an accomplished chemist, all odour is removed from the naphtha, and the smell of vegetable leather is rendered thereby less in strength, if anything, than that of leather. The principal objects to which it is at present applied, although it is obvious it will take a wider range of usefulness than leather itself, are carriage and horse aprons, antigropola, soldiers' belts, buckets which pack flat, harness of every description, bookbinding, &c. For, the latter, its toughness, washable quality and resistance to stains, render it remarkably fitted. Its thickness, which may be carried to any extent, is obtained by additional backings of linen, &c., cemented with the caoutchouc, and its strength is something marvellous, while in the all-important commercial view, it is but one-third the price of leather. Many of the articles we were shown possessed the appearance of much elegance and finish; but it was curious to observe, that although most of them could be made without a stitch, and within the factory itself, a deference to the feelings of the workmen in the several trades has been shown by the firm, and the material is given out as ordinary leather, to undergo the process of the needle, which it submits to with a greater facility than its original prototype.'

LEAVEN. Under Bread, the employment of yeast is fully explained. A few particulars relative to the French leaven may not, however, be out of place.

In Paris, where bread-making has been brought to a high degree of perfection, the fermentation is produced chiefly by the gluten of the dough, yeast being used merely to facilitate the action. A lump of dough remaining from the last batch of bread, and consisting of 8 lbs. flour and 4 lbs. of water, is left to itself for ten hours: in this state it is called *fresh leaven* (*levain de chef*). By kneading this with another quantity of 8 lbs. flour and 4 lbs. water, the *once revived leaven* (*levain de première*) is obtained. After another interval of eight hours, 16 lbs. of flour and 8 lbs. water are added, forming the *twice revived leaven* (*levain de seconde*); and after three hours more 100 lbs. flour and 52 lbs. water, containing ¼ to ⅓ lb. beer-yeast are added, forming the finished leaven (*levain de tout point*). The 200 lbs. leaven thus obtained are mixed after two hours with 132 lbs. flour and 68 lbs. water containing ½ lb. of yeast in suspension, and 2 lbs. common salt dissolved. This quantity of dough serves for five or six bakings. For the first baking half the dough (200 lbs.) is made into loaves of the required size and form, which are exposed for a while in shallow baskets to a temperature of 25° C. (77° F.), and then transferred to the oven. The bread thus obtained has a sourish taste and dark colour. The remaining half of the dough is again mixed with 132 lbs. of flour, 70 lbs. water, ½ lb. yeast, and the requisite quantity of salt, the half of this quantity of dough is then formed into loaves, left to ferment, and baked. The same operation is repeated three times, one-half of the dough being each time mixed with 130 lbs. flour and 1½ lb. yeast, and the proper quantity of water and salt. The last stage yields the finest and whitest bread. See Watts's 'Dictionary of Chemistry.'

LECANORIC ACID. An acid obtained from a South American variety of the *Roccella tinctoria.*

LECYTHIDACEÆ. The Brazil-nut order, remarkable for the edible seeds of many of its members. The *Lecythis ollaria* is found in the forests of Brazil and Cumâna. The fruit is about the size of a child's head; and it contains numerous edible seeds. The natives, who eat the seeds, and use the case for various purposes, call the fruit 'the monkey pots.' The *L. Zapucajo* is a native of Guiana: its fruit is about the size of the above; it contains numerous seeds, larger than almonds, and of an agreeable taste. These are the 'sapucaya' nuts of the fruiterers' shops. The Brazil-nuts are the produce of the juvia tree (*Bertholletia excelsa*). See BRAZIL NUTS.

LEDUM PALUSTRE. This plant is employed in Russia to tan the skins of goats, calves, and sheep, into a reddish leather of an agreeable smell; as also in the preparation of the oil of birch, for making what is commonly called Russia leather.

LEER. An arched building, forming an annealing furnace, in which glass is tempered or annealed.

LEGUMINE. A name applied to vegetable casein, in allusion to its occurrence in the seeds of many of the *Leguminosæ*, or Pea and Bean family.

LEMNIAN EARTH. A yellowish-grey earth, obtained from Lemnos by the Greeks. It is very similar to fuller's earth.

LEMONS. The fruit of the *Citrus limonum*. Both the juice and the peel of the fruit are employed medicinally, and in the preparation of lemonade. See CITRIC ACID, and OILS, ESSENTIAL.

LEMON GRASS. The *Andropogon citratum* (De Can.). This, and certain allied species, yield fragrant essential oils imported from India under the name of lemon grass and citronelle oils.

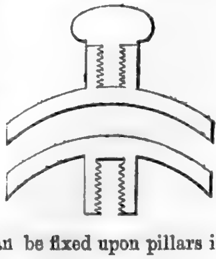
LENS. (*Lentille*, Fr.; *Linsenglas*, Ger.) Lenses are transparent bodies, usually made of glass, which by their curvature either concentrate or disperse the rays of light. Lenses are of the following kinds:—*Double convex*: having the same or a different degree of convexity on either side. *Plano-convex*, having one plane and one convex surface. *Concavo-convex*, having one concave and one convex side, commonly called *meniscus* lenses. *Plano-concave*, having one plane surface and one concave one; and the *double concave* lens.

The first three, which are thicker in the middle than at the edge, are *converging lenses*, because they occasion the rays of light to converge in passing through them. The others, which are thicker at the edges than in the middle, and therefore cause the pencils of light refracted through them to diverge, are called *diverging* lenses.

For the most complete examination of the laws regulating the construction of lenses, and the action of these on the rays of light, we must refer the reader to Sir John Herschel's admirable treatise on *Light* in the *Encyclopædia Metropolitana*. In this work we have only to deal with the mode of manufacturing the ordinary varieties. The spherical surfaces are produced by grinding them in counterpart tools, or discs of metal, prepared to the same curvature as the lenses. For the formation of the grinding tools, a concave and a convex template are first made to the radius of the curvature of the required lens. The templates of large radius are sometimes cut out of crown glass. More usually the templates are made out of sheet brass, the templates of long radii are cut with a strong radius bar and cutter, and those of only a few inches radius are cut in the turning-lathe. The brass concave and convex gauges are cut at separate operations, as it is necessary to adjust the radius to compensate for the thickness of the cutter, and the brass templates are not usually corrected by grinding, as practically it is found more convenient to fit the tools themselves together. The templates, having been made of the required radius, are used for the preparation of the grinding and polishing tools, which for concave lenses consist of a concave rough grinding-tool of cast iron, called a *shell*.

A pair of brass tools is, however, the most important part of the apparatus. One of these is concave and the other convex, made exactly to the curvature of the templates, and to fit each other as accurately as possible. The concave tool is used as the grinder for correcting the curvature of the lenses after they have been roughly figured in the concave shell, and the convex tool is employed for producing and maintaining the true form of the concave grinding-tool itself, and also that of the polisher. These polishers are adjusted with great accuracy. The concave tool is placed upon the convex, and they are first rubbed together dry, so that by the brightened parts the inequalities may be distinguished; they are then ground true, first by means of emery and water, and then with dry emery.

1382



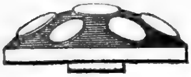
The annexed figure (1382) represents those tools, which are fitted with screws at the back, so that they can be fixed upon pillars in connection with the machinery for giving motion to them.

By grinding with sundry niceties of motion, which are required to produce the best effect, such as the production of motion which shall resemble as nearly as possible the kind of stroke which would be given by the hand, these tools are eventually brought to true spherical figures which fit each other exactly.

The glasses for lenses, being selected of suitable quality, are brought to a circular form by means of flat pliers called *shanks.* The pressure of the pliers applied near the edges of the glass causes it to crumble away in small fragments, and this process, which is called *shanking* or nibbling, is continued until the glasses are made circular, and of a little larger diameter than the finished size of the lenses.

A cement is made by mixing wood-ashes with melted pitch. Some nicety is required in the adjustment of the proportion, since the cement must not be too adhesive, nor must it be too hard or too brittle; generally about 4 lbs. of wood-ashes to 14 lbs. of pitch are employed. This when melted is poured on one side of the glasses to be ground, in small quantities at a time, until a sufficient quantity adheres to the back of the lens to form a handle. The glass is rough ground by rubbing it within the spherical shell. The glass is rubbed with large circular strokes, and the *shell* is usually placed within a shallow tray to catch the loose emery or polishing powder which may be employed. When one side is rough ground in this way, the glass is warmed to detach it from the handle, which is transferred to the other side and the operation repeated. When both sides are thus rudely formed, the lenses are cemented upon a runner. The best object-glasses for telescopes are ground and polished singly, while as many as four dozen of common spectacle glasses are ground and polished together. When many are thus fixed on one runner, the number must be such as will admit of their being arranged symmetrically around a central lens, as 7, 13, or 21; or sometimes 4, form the nucleus, and then the numbers run 14, 30. Lenses of ordinary quality are usually ground true and polished 7 at a time. This runner with its lenses attached is shown in *fig.* 1383.

1383



The cement at the back of the lenses is first flattened with a heated iron. The cast-iron runner is heated just sufficiently to melt the cement, and carefully placed upon the cemented backs of the lenses. As soon as the cement is sufficiently softened to adhere firmly to the runner, it is coated with a wet sponge, as the cement must only be so far fused as to fill up the spaces nearly, but not quite, level with the surface of the lenses. The block of lenses is now mounted upon a post, and ground with the concave brass tool, *fig.* 1382, motion being given to it either by the hand or by machinery similar to the sweeping motion already named. As the grinding proceeds, the fineness of the emery-powder employed is increased, until in the last operation it is sufficiently fine to produce a finely-polished surface. This grinding being completed successfully, the lenses have to be polished. The polisher is made by warming a cast-iron shell, and coating it uniformly about one quarter of an inch thick with melted cement. A piece of thick woollen cloth is cut to the size of the polisher and secured to it, and pressed into form by working the brass tool within it. When this is properly adjusted it is covered with very finely-divided putty-powder, sprinkled with a little water, and the powder worked into the pores of the cloth with the brass convex tool. Repeated supplies of putty-powder are put on the polisher until it is made quite level, and it is worked smooth with the tool. Many hours are expended in the proper preparation of a polisher. When completed it is fixed upon the block of lenses still fixed to the post, and worked with wide and narrow elliptical strokes. Where a very large number of glasses are ground or polished at the same time, this peculiar motion is imitated by the excentric movement of a lever attached to the revolving shaft. In the processes of grinding and polishing, other materials beside emery and putty-powder are sometimes employed, such as *raddle,* an earthy oxide of iron, the finer kinds of which are much employed in the large lens manufactory at Sheffield.

The best account of these processes and of the instruments used is by the late Andrew Ross, in the fifty-third volume of the *Transactions of the Society of Arts.* In *Holtzapffel's Mechanical Manipulation* there is also some practical information. See PHOTOGRAPHY.

LENTILS. The seeds of *Ervum lens,* a leguminous plant, from which the flour called *Ervalenta,* or *Revalenta,* is prepared.

LEPIDINE. $C^{10}H^9N$ ($\mathbf{C^5H^9N}$). A volatile base, homologous with chinoline, found in coal-naphtha and in the fluid produced by distilling cinchonine with potash.

LEPIDOCROCITE. A scaly or fibrous variety of Göthite, or hydrous peroxide of iron. See IRON.

LEPIDOLITE, or *Lithia Mica.* A beautiful purple mineral, which occurs in fine masses on Mount Hradisko, near Rosna, in Moravia. It is remarkable for the large quantity of lithia which it contains, and also for its containing the newly-discovered metal rubidium. See SPECTRUM ANALYSIS.

LEPIDOMELANE. An iron-potash mica, of black colour.

LETTSOMITE. A beautiful blue velvety mineral, from the Banat, first described by Dr. J. Percy. It is a hydrous sulphate of copper, of rare occurrence.

LETTUCE. The *Lactuca sativa*, cultivated as a salad. 'Lettuce opium' is prepared from this species, and from *L. virosa*, a more highly narcotic species.

LEUCANILINE. If a solution of *rosaniline* is left in contact with metallic zinc, or treated with sulphide of ammonium, it is rapidly decomposed. The rosaniline disappears, and is transformed into a remarkable base, which has received the name of *leucaniline*, and which may be obtained in completely colourless needles scarcely soluble in water, very soluble in alcohol. Its formula is:—

$$C^{20}H^{21}N^{3}\ (\mathbf{C^{10}H^{21}N^{3}}).$$

The salts of leucaniline are also colourless, easily crystallisable, and very soluble in water, from which they may be precipitated by the addition of an excess of acid.

There exists an extremely remarkable relation between the composition of leucaniline and that of rosaniline:—

Rosaniline	$C^{20}H^{19}N^{3}$ ($\mathbf{C^{10}H^{19}N^{3}}$).
Leucaniline	$C^{20}H^{21}N^{3}$ ($\mathbf{C^{10}H^{21}N^{3}}$).

Leucaniline differs therefore from rosaniline simply by containing two atoms more of hydrogen.

The two bases bear to each other the relation which exists between blue and white indigo:—

Blue indigo	$C^{16}H^{10}N^{2}O^{2}$ ($\mathbf{C^{8}H^{10}N^{2}O}$).
White indigo	$C^{16}H^{12}N^{2}O^{2}$ ($\mathbf{C^{8}H^{12}N^{2}O}$).

Leucaniline, as might have been expected from this interesting relation, may be reconverted into the red colouring matter by oxidising agents. On gently heating the colourless solution of hydrochlorate of leucaniline with peroxide of barium, perchlorides of iron or platinum or chromate of potassium, the liquid at once re-assumes the splendid colour of the rosaniline salts. (*Hofmann.*)

LEUCITE. A mineral found in volcanic rocks, containing usually 56·10 of silica, 23·10 of alumina, and 21·15 of potash. The finest and most beautiful crystals are found in the older lavas of Vesuvius and Rocca Monfina, and in the neighbourhood of Rome. It is sometimes called the *white garnet*, from the similarity of its crystallisation to that of the common garnet. Kirwan calls it the *white garnet of Vesuvius*. It was always supposed that leucite crystallised in the cubic system until Vom Rath showed, in 1872, that the crystals belonged to the tetragonal system.

LEUCOLINE. A synonym of LEUKOL.

LEUCOPYRITE. An arsenide of iron, resembling Lölingite.

LEUKOL. See CHINOLINE.

LEVEL (*a mining term*). An adit gallery or horizontal working in a mine.

LEVIGATION is the mechanical process whereby hard substances are reduced to a very fine powder.

LEVULOSE. A kind of sugar which turns the plane of polarisation of a ray of light towards the left hand.

LEWIS is the name of one kind of shears used in cropping woollen cloth.

LIAS. Under this term are comprehended the strata which intervene between the Trias, or New Red Series, and the Inferior Oolite. In the aggregate they are of considerable thickness, and occupy a large area in this country, stretching in a north-easterly direction from the sea west of Lyme Regis, in Dorsetshire, to Redcar, on the coast of Yorkshire. The strata which compose the Liassic series consist, in the lower part, of compact argillaceous limestone, alternating with or forming *layers* in clay, to a provincial pronunciation of which word the name *lias* probably owes its origin. This limestone forms the base of a thick deposit of blue clays and marls, which are overlaid by a series of sands and sandstone, called Marlstone; these in their turn are separated from another mass of sands, which form the uppermost member of the group, by a stratum of clay, known as the Upper Lias Clay.

By the term lias, however, is ordinarily only understood the calcareous and argillaceous division, which constitutes the lower section of the entire formation.

In an economical point of view, it is of considerable value from its furnishing a useful and durable stone, both for building and paving; for the latter purpose it is particularly suited, not only from the large dimensions of the flags it affords, but on account of its occurrence in thin layers, which, in many cases, when required for rough purposes only, are used in the state in which they are taken from the quarry, without undergoing subsequent dressing. The lime furnished by the blue lias limestone is also well known, and in great request, some of the beds possessing the valuable property of forming hydraulic mortars and cements, for manufacturing which it is collected from the shore and the sea-cliffs at Charmouth, and largely quarried at Lyme Regis and the neighbourhood. See HYDRAULIC CEMENTS.

The clayey members of the lias furnish a poor and cold agricultural soil, which is chiefly devoted to pasture, but the land upon the marlstone is, on the contrary, of a very rich and fertile description, and constitutes a district, where it prevails, that is marked by the luxuriance of its crops and the excellence of the cider it produces. In the upper part, it contains beds of ferruginous, brown, calcareous sandstone, which is used for building purposes in the neighbourhoods where it occurs. The sandstone is always more or less of a ferruginous character, but in some instances the ferruginous ingredient prevails to such a degree, as to constitute a valuable ore of iron, as in the neighbourhood of Blenheim, to which attention has been directed by Mr. Edward Hull, of the Geological Survey.

Like the marlstone, the calcareous sands of the uppermost portion of the liassic series also furnish a rich agricultural soil. Until recently, these sands were considered to form the base of the inferior oolite series, but the researches of Dr. Wright render it highly probable that they should, with more propriety, be classed with the underlying lias, rather than with the oolitic strata.[1]

The stone found at Cotham and other places in the neighbourhood of Bristol, and which has in consequence received the name of *Cotham marble*, and has also been called *ruin*, or *landscape marble*, from the curious delineations displayed upon polished sections of it, resembling trees, landscapes, &c., is a limestone from the lower part of the lias.—H. W. B.

LIBAVIUS, FUMING LIQUOR OF, is the bichloride of tin, prepared by dissolving that metal with the aid of heat in *aqua regia*, or by passing chlorine gas through a solution of muriate of tin till no more gas be absorbed, evaporating the solution, and setting it aside to crystallise. The anhydrous bichloride is best prepared by mixing four parts of corrosive sublimate with one part of tin, previously amalgamated with just so much mercury as to render it pulverisable; and by distilling this mixture with a gentle heat, a colourless fluid, the dry bichloride of tin, or the proper fuming liquor of Libavius, comes over. When it is mixed with one-third of its weight of water it becomes solid. The first bichloride of tin is used in calico-printing. See CALICO-PRINTING.

LIBETHENITE. A hydrous phosphate of copper, named from one of its localities —Libethen, near Neusohl, in Hungary.

LICHEN. A certain set of plants, composed chiefly of cellular tissue devoid of spiral vessels, with the stems and leaves undistinguishable, are termed Thallogens. These are of two kinds, the first admitting of two divisions :—

1. *Aquatic* thallogens, or such as are nourished through their whole surface by water, are ALGÆ. *Aërial* thallogens nourished through their whole surface by air are LICHENS.

2. Thallogens nourished through their *thallus* (spawn or mycelium) by juices derived from the matrix are FUNGI.

Lichens are numerous, as *Ground liverwort*, *Cup moss*, and *Tree lungwort*, used in Siberia as a substitute for hops in brewing; *Gyrophora*, employed by the hunters in the arctic regions as an article of food, under the name of *tripe de roche*; *Reindeer moss*, and *Iceland moss*, much used in this country as a remedy for coughs; the *Common yellow wall lichen*, and some others.

The *Tinctorial lichens* are also numerous. They furnish four principal colours, brown, yellow, purple, and blue.

Gyrophora pustulata and *Sticta pulmonaria* yield brown colours. The latter, with mordants of tin and cream of tartar, produces on silk a durable carmelite colour. (*Guibourt.*)

Parmelia parietina and *Evernia vulpina* produce yellows; the yellow principle of the former being called *chrysophanic acid*, that of the latter *vulpinic acid*.

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[1] The evidence brought forward by Dr. Wright in favour of the liassic origin of these sands is purely of a palæontological nature; physically, the most natural arrangement is to connect them rather with the inferior oolite than with the lias.—H. W. B.

Rocella, Lecanora, Variolaria, &c., yield purple and blue colours. In this country archil and cudbear, purple colours, are prepared from it. In Holland, a blue colour, litmus.

Dr. Stenhouse, to whom we are much indebted for many important inquiries connected with the applications of chemistry, has given the following table of the lichens:—

Lichens		Colorific Principles		Colouring Principles		Authority
Commercial Names	Locality	Names	Formulæ	Names	Formulæ	
S. American orchella weed	Lima, &c.	Alpha orsellic acid	$C^{32}H^{15}O^{13}+HO$	Orceine	$C^{18}H^{10}NO$	Stenhouse
Cape orchella weed	C. of Good Hope	Beta orsellic acid	$C^{34}H^{18}O^{14}+HO$	„	„	Stenhouse
Angola orchella weed	Africa	Erythric acid	$C^{20}H^{10}O^{9}+HO$	„	„	Stenhouse
Perelle moss (*Lecanora parella*)	Switzerland	Lecanoric acid	$C^{18}H^{8}O^{8}$	„	„	Shunck
Tartareous moss (*Lecanora tartarea*)	Norway	Gyrophoric acid	$C^{36}H^{18}O^{15}$	„	„	Stenhouse
Pustulatous moss (*Gyrophora pustulata*)	Norway	„	„	„	„	Stenhouse
Ragged hoary lichen (*Evernia prunastri*)	Scotland	Evernic acid	$C^{34}H^{15}O^{13}+HO$	..	..	Stenhouse
Usnea (*Florida, plicata,* and *nirta*)	Germany	Usnic acid	$C^{38}H^{7}O^{14}$	..	..	Rochleder and Heldt
Reindeer moss (*Cladonia rangiferina*)	..	„	„	..	..	„
Ramalina (*Fastigiata calicaris*)	..	„	„	..	..	„

See Archil; French Purple; Litmus; Orchella Weed.

LICKNER'S BLUE. The silicate of cobalt and potash.

LIEBIGITE. A hydrous carbonate of uranium and lime, named after the late Baron Liebig.

LIEVRITE. A silicate of iron, known as *Ilvaite* and *Jenite.*

LIGHT. (*Lumière,* Fr.; *Licht,* Ger.) The operation of light as an agent in the arts or manufactures has scarcely yet received attention. Sufficient evidence has, however, been collected to show that it is of the utmost importance in producing many of the remarkable changes in bodies which are desired in some cases as the result, but which in others are to be, if possible, avoided.

There is a very general misconception as to the power or principle to which certain phenomena, the result of exposure to sunshine, are to be referred. In general *light* is regarded as the principle in action, whereas frequently it has nothing whatever to do with the change. A few words therefore in explanation are necessary. The solar ray, commonly spoken of as *light,* contains, in addition to its *luminous power, calorific power, chemical power,* and, in all probability, *electrical power.* (See Actinism.) These phenomena can be separated one from the other, and individually studied. All the photographic phenomena are dependent upon the chemical (actinic) power. Many of the peculiar changes which are effected in organic bodies are evidently due to *light,* and the phenomena which depend entirely on heat are well known.

Herschel has directed attention to some of the most striking phenomena of *light,* especially its action upon vegetable colours. As these have direct reference to the permanence of dyes, they are deserving of great attention. The following quotation from Sir John Herschel's paper 'On the Chemical Action of the Rays of the Solar Spectrum, &c.,' will explain his views and give the character of the phenomena which he has studied. He writes:—

'The evidence we have obtained by the foregoing experiments of the existence of chemical actions of very different and, to a certain extent, opposite characters at the opposite extremities (or rather, as we ought to express it, in the opposite regions) of the spectrum, will naturally give rise to many interesting speculations and conclusions, of which those I am about to state will probably not be regarded as among the least so. We all know that colours of vegetable origin are usually considered to be destroyed and whitened by the continual action of light. The process, however, is too slow to be made the subject of any satisfactory series of experiments, and, in consequence, this subject, so interesting to the painter, the dyer, and the general artist, has been allowed to remain uninvestigated. As soon, however, as these evidences of a counterbalance of mutually opposing actions, in the elements of which the solar light consists, offered themselves to view, it occurred to me, as a reasonable subject of inquiry, whether this slow destruction of vegetable tints might not be due to the feeble amount of residual action outstanding after imperfect mutual compensation, in the ordinary way in which such colours are presented to light, *i.e.* to mixed rays. It appeared therefore to merit inquiry, whether such colours, subjected to the uncompensated action of the elementary rays of the spectrum, might not undergo changes differing both in kind and in degree which mixed light produces on them, and might not, moreover, by such changes indicate chemical properties in the rays themselves hitherto unknown.

'One of the most intense and beautiful of the vegetable blues is that yielded by the blue petals of the dark velvety varieties of the common heartsease (*Viola tricolor*). It is best extracted by alcohol. The alcoholic tincture so obtained, after a few days keeping in a stoppered phial, loses its fine blue colour, and changes to a pallid brownish red, like that of port wine discoloured by age.

'When spread on paper it hardly tinges it at first, and might be supposed to have lost all colouring virtue, but that a few drops of very dilute sulphuric acid sprinkled over it, indicate by the beautiful and intense rose colour developed where they fall, the continued existence of the colouring principle. As the paper so moistened with the tincture dries, however, the original blue colour begins to appear, and when quite dry is full and rich. The tincture by long keeping loses this quality, and does not seem capable of being restored. But the paper preserves its colour well, and is even rather remarkable among vegetable colours for its permanence in the dark or in common daylight.

'A paper so tinged of a very fine and full blue colour, was exposed to the solar spectrum concentrated, as usual (October 11, 1839), by a prism and lens; a water-prism, however, was used in the experiment, to command as large an area of sunbeam as possible. The sun was poor and desultory; nevertheless, in half an hour there was an evident commencement of whitening from the fiducial yellow ray to the mean red. In two hours and a half, the sunshine continuing very much interrupted by clouds, the effect was marked by a considerable white patch extending from the extreme red to the end of the violet ray, but not traceable beyond that limit. Its commencement and termination were, however, very feeble, graduating off insensibly; but at the maximum, which occurred a little below the fiducial point (corresponding nearly with the orange rays of the luminous spectrum), the blue colour was completely discharged. Beyond the violet there was no indication of increase of colour, or of any other action. I do not find that this paper is discoloured by mere radiant heat unaccompanied with light.'

The late Dr. George Wilson of Edinburgh made some exceedingly interesting experiments *on the influence of sun light over the action of dry gases on organic colours.* The results arrived at were communicated to the British Association, and an abstract of the communication is published in their Transactions. The experiments were on chlorine, sulphurous acid, sulphuretted hydrogen, carbonic acid, and a mixture of sulphurous and carbonic acid, oxygen, hydrogen and nitrogen on organic colouring matters. 'I had ascertained,' says Dr. George Wilson, 'the action of the gases mentioned already on vegetable colouring matters, so arranged, that both colouring matter and gas should be as dry as possible, the aim of the inquiry being to elucidate the theory of bleaching, by accounting for the action of dry chlorine upon dry colours. In the course of this inquiry, I ascertained that in darkness dry chlorine may be kept for three years in contact with colours without bleaching them, although when moist it destroys their tints in a few seconds (see BLEACHING); and I thought it desirable to ascertain whether dry chlorine was equally powerless as a bleacher when assisted by sunlight. The general result of the inquiry was, that a few weeks sufficed for the bleaching of a body by chlorine in sunlight, where months, I may even say years, would not avail in darkness.' The form of the experiment was as follows:—Four tubes were connected together so as to form a continuous canal, through which a current of gas could be sent. Each tube contained a small glass rod, on which seven pieces of differently-coloured papers were spiked. It is not necessary here to state the colours employed, suffice it to say, that all the tubes thus contained seven different coloured papers, of different origins, and easily distinguishable by the eye. They were arranged in the same order in each tube, and were prepared as nearly as possible of the same shade. These papers were carefully deprived of every trace of moisture by a current of very dry air. The tubes were then filled with the gas, also dried, on which the experiment was to be made. One tube of each series was kept in darkness, two others were exposed in a western aspect behind glass, and the other was turned to the south in the open air.

The results were as follow:—In the dark chlorine tube the colours were very little altered, and would probably have been altered less had not the tube been frequently exposed to light for the sake of examination. In the western tube, the original grey and green wallflower papers became of a bright crimson, the blue litmus bright red, and the brown rhubarb yellow. The whole of the chlorine had apparently entered into combination with the colouring matters, for the yellow tint of the gas had totally disappeared. In the southern tube the colour of the chlorine could still be seen, the reddening action was less decided, and the bleaching action was more powerfully evinced. The general result was that the action of sunlight is less uniform than might have been expected in increasing the bleaching power of chlorine, or while some tints rapidly disappeared under its action assisted by light, other colours remained, in apparently the very same circumstances, unaffected.

Sulphurous acid, if thoroughly dried, may be kept for months in contact with dry colours without altering them; under the influence of sunlight it however recovers to some extent its bleaching power.

Sulphuretted hydrogen acts as a weak acid, and readily as a bleacher when moist, and becomes inactive in both respects if made dry and kept in darkness. With the assistance of sunlight it recovers in no inconsiderable degree its bleaching power.

Oxygen is a well-known bleaching agent, but when dry its action upon colouring matter in the dark is extremely slow. In sunlight, however, it recovers its bleaching power.

Carbonic acid, when dry in darkness, loses all power on colouring matter, but a faint bleaching action is exerted by it under exposure to sunlight.

Hydrogen is without any action when dry upon colours, but it acquires a slight decolorising power when exposed to sunshine.

'The general result,' concludes Dr. George Wilson, 'of this inquiry, so far as it has yet proceeded, is, that the bleaching gases, viz. chlorine, sulphurous acid, sulphuretted hydrogen, and oxygen, lose nearly all their bleaching power, if dry and in darkness, but all recover it, and chlorine in a most marked degree, by exposure to sunlight.'

All these experiments appear to show that the action of the solar rays on vegetable colours is dependent upon the power possessed by one set of rays to aid in the oxidation or chemical changes of the organic compound constituting the colouring matter. The whole matter requires careful investigation.

It is a proved fact, that colouring matters, either from the mineral or the vegetable kingdoms, are much brighter when they are precipitated from their solutions in bright sunshine, than if precipitated on a cloudy day or in the dark. It must not be supposed that all the changes observed are due to chemical action; there can be no doubt but many are purely physical phenomena, that is, the result of molecular change, without any chemical disturbance.

LIGHT CARBURETTED HYDROGEN. Marsh-gas or fire-damp.

LIGHT, ELECTRIC. See ELECTRIC LIGHT.

LIGHTHOUSE. The importance of lights of great power and of a distinguishable character around our coasts is admitted by all. One of the noblest efforts of humanity is certainly the construction of those guides to the mariners upon rocks which exist in the tracks of ships, or upon dangerous shores and the mouths of harbours. This is not the place to enter largely upon any special description of the lights which are adopted around our shores; a brief account only will be given of some of the more remarkable principles which have been introduced of late years by the Trinity Board.

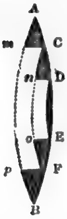
The early lighthouses appear to have been illuminated by coal or wood fires contained in 'chauffers.' The Isle of Man light was of this kind until 1816. The first decided improvement was made by Argand, in 1784, who invented a lamp with a circular wick, the flame being supplied by an external and internal current of air. To make these lamps more effective for lighthouse illumination, and to prevent the ray of light escaping on all sides, a reflector was added in 1780 by M. Lenoir; this threw the light forward in parallel rays towards such points of the horizon as would be useful to the mariner. Good reflectors increase the luminous effect of a lamp about 400 times; this is the 'catoptric' system of lighting. When reflectors are used, there is a certain quantity of light lost, and the 'dioptric' or *refracting* system, invented by the late M. Augustin Fresnel in 1822 is designed to obviate this effect to some extent: the 'catadioptric' system is a still further improvement, and acts both by refraction and reflection. Lights of the first order have an interior radius or focal distance of 36·22 inches, and are lighted by a lamp of four concentric wicks, consuming 570 gallons of oil per annum. Recently (1874) mineral oil has been used with much advantage and economy in the lighthouses of America.

The following notices may be of interest:—The Eddystone Lighthouse, 9½ miles from the Rame Head, on the coast of Cornwall, was erected of timber by Winstanley in 1696–98, and was washed away in 1703. It was rebuilt by Rudyard in 1706, and destroyed by fire in 1755. The present edifice was erected by Smeaton 1757–59. Tallow candles were used in the first instance for the lights; but in 1807 argand lamps, with paraboloidal reflectors of silvered copper were substituted.

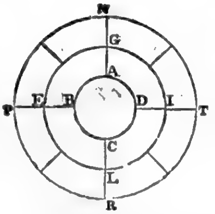
The Skerryvore Rocks, about 12 miles south-west of Tyree on the coast of Argyleshire, lying in the track of the shipping of Liverpool and of the Clyde had long been regarded with dread by the mariners frequenting these seas. The extreme difficulty of the position, exposed to the unbroken force of the Atlantic Ocean, had alone deterred the Commissioners of Northern Lights from the attempt to place a light upon this dangerous spot; but in 1834 they caused the reef to be surveyed, and in 1838 Mr. Alan Stevenson, their engineer, inheriting his father's energy and scientific skill, commenced his operations upon a site from which 'nothing could be seen for miles around but white foaming breakers, and nothing could be heard but the howling of the winds and the lashing of the waves.' His design was an adaptation of Smeaton's tower of the Eddystone to the peculiar situation, a circumstance with which he had to contend. He established a circular base 42 feet in diameter, rising in a solid mass of gneiss or granite, but diminishing in diameter to the height of 26 feet, and presenting an even concave surface all round to the action of the waves. Immediately above this level the walls are 9·58 feet thick, diminishing in thickness as the tower rises to its highest elevation, where the walls are reduced to 2 feet in thickness, and the diameter to 16 feet. The tower is built of granite from the islands of Tyree and Mull, and its height from the base is 138 feet 8 inches. In the intervals left by the thickness of the walls are the stairs, a space for the necessary supply of stores, and a not uncomfortable habitation for three attendants. The rest of the establishment, stores, &c., are kept at the depôt in the island of Tyree. The light of the Skerryvore is revolving, and is produced by the revolution of eight annular lenses around a central lamp, and belongs to the first order of dioptric lights in the system of Fresnel, and may be seen from a vessel's deck at a distance of 18 miles.

Some of the lenticular arrangements must now claim attention. The appearance of light called short eclipses has hitherto been obtained by the following arrangement:—An apparatus for a fixed light being provided, composed of a central cylinder and two zones of catadioptric rings forming a cupola and lower part, a certain number of lenses are arranged at equal distances from each other, placed upon an exterior moveable frame making its revolution around the apparatus in a given period. These lenses, composed of vertical prisms, are of the same altitude as the cylinder, and the radius of their curves is in opposite directions to those of the cylinder, in such a manner that at their passage they converge into a parallel pencil of light, all the divergent rays emitted horizontally from the cylinder producing a brilliant effect, like that obtained by the use of annular lenses at the revolving lighthouses. Large lenses, or any large masses of glass, are liable to striæ, which by dispersing, occasion a loss of much light.

1384



1385



'In order to improve a solid lens formed of one piece of glass whose section is A, *m*, *p*, B, F, E, D, C, A (*fig.* 1384), Buffon proposed to cut out all the glass left white in the figure, namely, the portions between *m p* and *n o*, and between *n o* and the left-hand surface of D E. A lens thus constructed would be incomparably superior to a solid one, but such a process we conceive to be impracticable on a large scale, from the extreme difficulty of polishing the surfaces A *m*, B *p*, C *n*, F *o*, and the left-hand surface of D E; and even if it were practical, the greatest imperfections of the glass might happen to occur in the parts which are left. In order to remove these imperfections and to construct lenses of any size,' says Sir David Brewster, 'I proposed in 1811 to build them up of separate zones or rings, each of which rings was again to be composed of separate segments, as shown in the front view of the lens in *fig.* 1385. This lens is composed of one central lens A B C D, corresponding with its section D E in *fig.* 1384; of a middle ring G E L I, corresponding to C D, E F, and consisting of 4 segments; and another ring N P R T, corresponding to A C, F B, and consisting of 8 segments. The preceding construction obviously puts it in our power to execute those lenses, to which I have given the name of *polyzonal lenses*, of pure flint glass free from veins; but it possesses another great advantage, namely, that of enabling us to correct very nearly the spherical aberration by making the foci of each zone coincide.'

This description will enable the reader to understand the system which has been adopted by Fresnel, and carried out by the French Government and by our own Commissioners of Lights.

In the fixed dioptric light of Fresnel, the flame is placed in the centre of the apparatus, and within a cylindric reflector of glass, of a vertical refracting power, the breadth and height of a strip of light emitted by it being dependent upon the size of the flame and the height of the reflector itself; above and below is placed a series of reflecting prismatic rings or zones for collecting the upper and lower divergent rays, which, falling upon the inner side of the zone are refracted, pass through the second side where they suffer total reflection, and, passing out on the outer side of the zone, are again refracted. The effect of these zones is to lengthen the vertical strip of light, the size of which is dependent upon the breadth of the flame and the height of the apparatus.

In Fresnel's revolving lighthouse, a large flame is placed in the centre of a revolving frame which carries a number of lenses on a large scale and of various curvatures for the avoidance of spherical aberration. With the view of collecting the divergent rays above the flame, an arrangement of lenses and silvered mirrors is placed immediately over it. By this compound arrangement the simply revolving character of the apparatus is destroyed, as, in addition to the revolving flash, a vertical and fixed light is at all times seen, added to which a great loss of light must be sustained by the loss of metallic reflectors. In 1851, Messrs. Wilkins and Letourneau introduced a catadioptric apparatus of great utility, which was thus described by them:—

The first improvement had special reference to the light, and produced a considerable increase in its power, whilst the simplicity of the optical arrangements was also regarded. It consisted, first, in completely dispensing with the moveable central cylindrical lenses; secondly, it replaced these by a single revolving cylinder composed of four annular lenses and four lenses of a fixed light introduced between them; but the number of each varying according to the succession of flashes to be produced in the period of revolution.

The second improvement consisted in a new method of arranging the revolving parts, experience having shown that the arrangements in use were very faulty. A short time is sufficient for the action of the friction-rollers, revolving on two parallel planes, to produce, by a succession of cuttings, a sufficiently deep groove to destroy the regularity of the rotatory movement. To obviate this great inconvenience the friction-rollers were so placed and fitted, on an iron axis with regulating screws and traversing between two bevelled surfaces, and when an indentation was made in one place they could be adjusted to another part of the plates which is not so worn.

The third improvement produced the result of an increase of the power of the flashes in revolving lighthouse apparatus to double what had been obtained hitherto. By means of lenses of vertical prisms placed in the prolongation of the central annular lenses, the divergent rays emerging from the catadioptric zone were brought into a straight line, and a coincidence of the three lenses obtained.

The whole of the prisms, lenses, and zones are mounted with strength and simplicity, accurately ground and polished to the correct curves according to their respective positions, so as to properly develope this beautiful system of Fresnel. The glass of which they are composed should be of the clearest crystal colour, and free from that green hue which so materially reduces the power of the light, and is considered objectionable for apparatus of this kind. The lamp by which the apparatus is to be lighted consists of a concentric burner with four circular wicks attached to a lamp of simple construction, the oil being forced up to the burner by atmospheric pressure only, so that there are no delicate pumps or machinery to become deranged.

Stevenson's Revolving Lighthouse.—This apparatus consists of two parts. The principal part is a right octagonal hollow prism composed of eight large lenses, which throw out a powerful beam of light whenever the axis of a single lens comes in the line between the observer and the focus. This occurs once in a minute, as the frame which bears the lens revolves in eight minutes on the rollers placed beneath. The subsidiary parts consist of eight pyramidal lenses inclined at an angle of 30° to the horizon, and forming together a hollow truncated cone, which rests above the flame like a cap. Above these smaller lenses (which can only be seen by looking from below) are placed eight plane mirrors, whose surfaces being inclined to the horizon at 50° in the direction opposite to that of the pyramidal lenses, finally cause all the light made parallel by the refraction of these lenses to leave the mirror in a horizontal direction. The only object of this part is to turn to useful account, by prolonging the duration of the flash, that part of the light which would otherwise escape into the atmosphere above the main lenses. This is effected by giving to the upper lenses a slight horizontal divergence from the vertical plane of the principal lenses. Below are five tires of totally reflecting prisms, which intercept the light that passes below the great lenses, and by means of two reflections and an intermediate refraction project them in the shape of a flat ring to the horizon.

Stevenson's fixed dioptric apparatus of the first order (same as that at the Isle of May, with various improvements). The principal part consists of a cylindric belt of glass which surrounds the flame in the centre, and by its action refracts the light in a *vertical* direction upward and downward, so as to be parallel with the focal plane of the system. In this way it throws out a flat ring of light equally intense in every direction. To near observers, this action presents a narrow vertical band of light, depending for its breadth on the extent of the horizontal angle embraced by the eye. This arrangement therefore fulfils all the conditions of a fixed light, and surpasses in effect any arrangement of parabolic reflectors. In order to save the light which would be lost in passing above and below the cylindrical belt, curved mirrors with their common focus in the lamp were formerly used; but by the present engineer, the adaptation of *catadioptric* zones to this part of the apparatus was, after much labour, successfully carried out. These zones are triangular, and act by *total* reflection, the inner face *refracting*, the second *totally reflecting*, and the third or outer face, a second time *refracting*, so as to cause the light to emerge *horizontally*. The apparatus has received many smaller changes by the introduction of a new mode of grouping the various parts of the framework, by which the passage of the light is less obscured in every azimuth.

Mechanical lamps of four wicks are used in these lighthouses; in these the oil is kept continually overflowing by means of pumps which raise it from the cistern below; thus the rapid carbonisation of the wicks, which would be caused by the great heat, is avoided. The flames of the lamp reach their best effect in three hours after lighting, *i.e.* after the whole of the oil in the cistern, by passing and repassing over the wicks repeatedly, has reached its maximum temperature. After this the lamp often burns fourteen hours without sensible diminution of the light, and then rapidly falls. The height varies from sixteen to twenty times that of the argand flame of an inch in diameter; and the quantity of oil consumed by it is greater nearly in the same proportion.

In *Stevenson's ordinary parabolic reflector*, rendered *holophotal* (where the entire light is parallelised) by a portion of a catadioptric annular lens, the back part of the parabolic conoid is cut off, and a portion of a spherical mirror substituted, so as to send the rays again through the flame; while his *holophotal catadioptric annular lens apparatus* is a combination of a hemispherical mirror and a lens having totally-reflecting zones; the peculiarity of this arrangement is, that the catadioptric zones, instead of transmitting the light in parallel horizontal plates, as in Fresnel's apparatus, produces, as it were, an extension of the lenticular or quaquaversal action of the central lens by assembling the light around its axis in the form of concentric hollow cylinders.

Mr. Chance, of Birmingham, constructed a lighthouse which may be regarded as Fresnel's revolving light rendered holophotal. This arrangement was divided into three compartments, the upper and lower of which were composed respectively of thirteen and six catadioptric zones which produce the vertical strip of light extending the whole length of the apparatus, and is similar to Fresnel's dioptric light. The central or catoptric compartment consisted of eight lenses of three feet focal length, each of which was the centre of a series of eleven concentric prismatic rings, designed to produce the same refractive effect as a solid lens of equal size. These compound lenses were mounted upon a revolving frame and transmitted horizontal flashes of light as they successively rotated. The motion was communicated to the frame by a clock movement, and performs one revolution in four minutes; consequently, as there are eight lenses, a flash of light is transmitted every thirty seconds to the horizon.

LIGN ALOES. This wood is supposed to be the produce of *Aquilaria Agallocha*, one of the Lace-bark order.

LIGNEOUS MATTER is vegetable fibre. See FIBRE, VEGETABLE.

LIGNITE. Under BROWN COAL, and COAL, the characteristics of lignite have already received attention, therefore little further need be said. The term lignite should be confined to fossil wood, or, still more correctly to wood which has undergone one of the changes leading *towards* the production of coal. If wood is buried in moist earth there is the production of carbonic acid from the elements of the wood, and the wood is changed into either lignite or brown coal. Lignite and coal differ chemically from each other. Lignite yields by dry distillation acetic acid and acetate of ammonia, whereas coal produces only an ammoniacal liquor. (*Kremers.*) Woody fibre gives rise to acetic acid; therefore, lignite must still contain undecomposed woody fibre. The following table gives the composition of several well-known lignites:—

	Carbon	Hydrogen	Oxygen and Nitrogen	Earthy matter	Chemist
From Uttweiler . . .	77·9	2·6	19·5	1·0	Karsten
„ Hungary . . .	67·3	4·3	...	0·8	Nendtwich
„ the Rhône. . .	72·2	4·9	20·1	1·8	Regnault
„ Meissner . . .	68·6	5·9	19·0	2·3	Gräger
„ Bovey Heathfield .	67·9	5·8	24·8	...	Vaux

The products of the destructive distillation of lignite, by B. Niederstadt is well deserving attention.—The lignites examined came from the Rhenish-Hessian basin. 1. Lignite from Meissner, of a red-brown colour and woody texture; specific gravity 1·12. 2. Lignite from Rheinhardswalde, grey or black, containing abundance of resin; specific gravity 1·13. 3. Brilliant lignite of Meissner, black, fracture fibrous, lustre vitreous; specific gravity 1·32. 4. Lignite of Hirschberg, brownish-black, in tree-like masses; specific gravity 1·35. The following is their elementary composition:—

	1	2	3	4
Carbon	51·238	58·782	69·995	60·302
Hydrogen	4·169	4·042	3·192	4·859
Oxygen	32·326	20·803	17·591	20·169
Nitrogen	0·175	0·150	0·123	0·121
Ash	0·795	5·940	5·470	3·167
Moisture	10·297	10·283	3·629	11·391

On distillation these lignites yielded solid, liquid, and gaseous products; at a dark-red heat, a brown tarry matter passing over along with combustible gases. To separate the watery portion from the tar, common salt was added to the mixture, heated to 40°. The quantity of tar, when freed from water, amounted to 4 to 5 per cent., and the watery products 48 to 55 per cent., containing acetic acid and ammonia. The oily matters distilled over at 95° to 220°, leaving a black pitchy residue. The distillate, on agitation with concentrated soda-lye, yields phenol. On fractional distillation, the portions passing over up to 150° contain pyrrol and picoline, which boils at 135°, and is distinguished from aniline by not giving a violet colouration with chloride of lime. The part passing over about 220° solidified on cooling, yielding a crystalline mass soluble in alcohol and ether. It melts at 49° to 51°, and is a paraffin formed of hydrocarbons C^nH^{2n}. It amounts to 1 per cent. of the lignite employed. The gaseous mixture, from the Meissner lignite, consisted of:—Hydrogen, 14·26; carbonic oxide, 40·12; marsh-gas, 10·29; nitrogen, 4·09; carbonic acid, 2·10; ethylene and superior hydrocarbons, 2·13. There appears, consequently, little prospect of using the gases from lignite for lighting purposes.

In Prussia, Austria, and many other parts of the Continent, lignite forms a very important product, being largely employed for domestic and for manufacturing purposes. In this country, with the single exception of the Bovey Heathfield formation, which is used in the adjoining pottery, lignite is not employed. See COAL.

LIGNUM-VITÆ, or *Guaiacum* (*Guaiacum officinale* and *G. sanctum*), a very hard and heavy wood. The fibrous structure of this wood is very remarkable; the fibres cross each other sometimes as obliquely as at an angle of 30° with the axis, as if one group of the annual layers wound to the right, the next to the left, and so on, with any exactitude. The wood can hardly be split, it is therefore divided by the saw. Lignum-vitæ is much used in machinery for rollers, presses, mills, &c., and for pestles and mortars, sheers for ship's blocks, skittle balls, and a great variety of other works requiring hardness and strength.

The gum guaiacum of the apothecary is extracted from this wood.

LILAC DYE. See Calico-Printing; Dyeing; and Aniline.

LIMA WOOD. See Brazil Wood.

LIME, THE. The *Citrus Limetta*, yielding the lime-juice so much esteemed for flavouring sherbet, punch, &c.

LIME. *Quicklime*, an *Oxide of Calcium.* This useful substance is prepared by burning calcareous stones in kilns or furnaces.

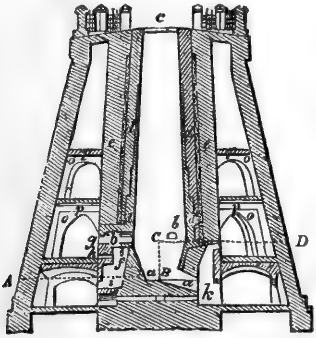
Limestone used to be calcined in a very rude kiln, formed by inclosing a circular space of 10 or 15 feet diameter, by rude stone walls 4 or 5 feet high, and filling the cylindrical cavity with alternate layers of turf or coal and limestone broken into moderate pieces. A bed of brushwood was usually placed at the bottom, to facilitate the kindling of the kiln. Whenever the combustion was fairly commenced, the top, piled into a conical form, was covered in with sods, to render the calcination slow and regular. This method being found relatively inconvenient and ineffectual, was succeeded by a permanent kiln built of stones or brickwork, in the shape of a truncated cone with the narrow end undermost, and closed at bottom by an iron grate. Into this kiln, the fuel and limestone were introduced at the top in alternate layers, beginning of course with the former; and the charge was either allowed to burn out, when the layer was altogether removed at a door near the bottom, or the kiln was successively fed with fresh materials, in alternate beds, as the former supply sunk down by the calcination, while the thoroughly-burnt lime at the bottom was successively raked out by a side door immediately above the grate. The interior of the lime kiln has been changed of late years from the conical to the elliptical form, and probably the best is that of an egg placed with its narrow end undermost, and truncated both above and below; the ground plot or bottom of the kiln being compressed so as to give an elliptical section, with an *eye* or draft-hole towards each end of that ellipse. A kiln thus arched in above gives a reverberatory heat to the upper materials, and also favours their falling freely down in proportion as the finished lime is raked out below; advantages which the conical form does not afford. The size of the draft-holes for extracting the quicklime, should be proportionate to the size of the kiln, in order to admit a sufficient current of air to ascend with the smoke and flame, which is found to facilitate the extrication of the carbonic acid. The kilns are called *perpetual*, because the operation is carried on continuously as long as the building lasts; and *draw-kilns*, from the mode of discharging them by raking out the lime into carts placed against the draft-holes. Three bushels of calcined limestone, or lime-shells, are produced on an average for every bushel of coals consumed. Such kilns should be built up against the face of a cliff, so that easy access may be gained to the mouth for charging, by making a sloping cart-road to the top of the bank.

Figs. 1386, 1387, 1388, 1389, represent the *lime-kiln* of Rüdersdorf near Berlin, upon the continuous plan, excellently constructed for economising fuel. It is triple, and yields a threefold product. *Fig.* 1388 is a view of it as seen from above; *fig.* 1389, the elevation and general appearance of one side; *fig.* 1386, a vertical section, and *fig.* 1387, the ground plan in the line A B C D of *fig.* 1386. The inner shaft *fig.* 1386, has the form of two truncated cones, with their larger circular ends applied to each other; it has the greatest width at the level of the fire-door *b*, where it is 8 feet in diameter; it is narrower below, at the discharge door, and at the top orifice, where it is about 6 feet in diameter. The interior wall *d*, of the upper shaft is built with hewn stones to the height of 38 feet, and below that for 25 feet, with fire-bricks *d′ d′*, laid stepwise. This inner wall is surrounded with a mantle *e*, of limestone, but between the two there is a small vacant space of a few inches filled with ashes, in order to allow of the expansion of the interior with heat taking place without shattering the mass of the building.

The fire-grate, *b*, consists of fire-tiles, which at the middle, where the single pieces press together, lie upon an arched support *f*. The fire-door is also arched, and is secured by fire-tiles. *g* is the iron door in front of that orifice. The tiles which form the grate have 3 or 4 slits of an inch wide for admitting the air, which enters through the canal *h*. The under part of the shaft from the fire to the hearth is 7 feet, and the outer enclosing wall is constructed of limestone, the lining being of fire-bricks. Here are the ash-pit *i*, the discharge outlet *a*, and the canal *k*, in front of the outlet. Each ash-pit is shut with an iron door, which is opened only when the space *i* becomes filled with ashes. These indeed are allowed to remain till they get cool enough to be removed without inconvenience.

The discharge outlets are also furnished with iron doors, which are opened only for taking out the lime, and are carefully luted with loam during the burning. The outer walls *l m n* of the kiln, are not essentially necessary, but convenient, because they afford room for the lime to lie in the lower floor, and the fuel in the second. The several stories are formed of groined arches *o*, and platforms *p*, covered over with limestone slabs. In the third and fourth stories the workmen lodge at night. See *fig.* 1389. Some enter their apartments by the upper door *q*, others by the lower door *s*. *r* is one of the chimneys for the several fireplaces of the workmen; *t*, *u*, *v* are stairs.

1386



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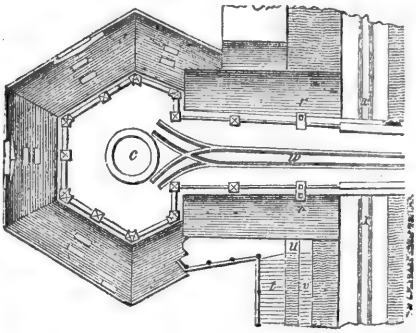

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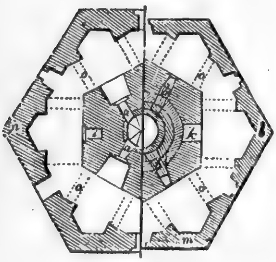

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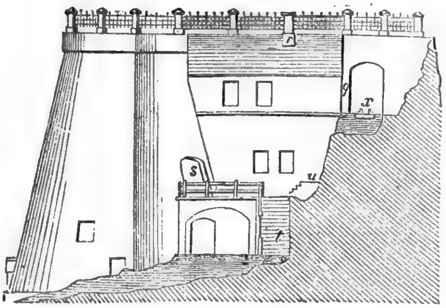


As the limestone is introduced at top, the mouth of the kiln is surrounded with a strong iron balustrade to prevent the danger of the people tumbling in. The platform (*fig.* 1388) is laid with rails *w*, for the waggons of limestone, drawn by horses, to run upon. *x* is another railway, leading to another kiln. Such kilns are named after the number of their fire-doors, single, twofold, threefold, fourfold, &c.; from three to five being the most usual. The outer form of the kiln also is determined by the number of the furnaces, being a truncated pyramid of equal sides, and in the middle of each alternate side there is a fireplace, and a discharge outlet. A cubic foot of limestone requires for burning, one and five-twelfths of a cubic foot of wood, and one and a half of turf.

When the kiln is to be set in action, it is filled with rough limestone, to the height C D, or to the level of the firing; a wood fire is kindled in *a*, and kept up till the lime is calcined. Upon this mass of quicklime a fresh quantity of limestone is introduced, not thrown in at the mouth, but let down in buckets, till the kiln is quite full; while over the top a cone of limestones is piled up, about 4 feet high. A turf-fire is now kindled in the furnaces *b*. Whenever the upper stones are well calcined, the lime under the fire-level is taken out, the superior column falls in, a new cone is piled up, and the process goes on thus without interruption, and without the necessity of once putting a fire into *a*; for in the space C B, the lime must be always well calcined. The discharge of lime takes place every 12 hours, and it amounts at each time in a threefold kiln, to from 20 to 24 Prussian *tonnes* of 6 imperial bushels each; or to 130 bushels imperial upon the average. It is found by experience that fresh-broken limestone, which contains a little moisture, calcines more readily than what has been dried by exposure for some time to the air: in consequence of the vapour of water promoting the escape of the carbonic acid gas; a fact well exemplified in distilling essential oils, as oil of turpentine and naphtha, which come over with the steam of water at upwards of 100° Fahr. below their natural term of ebullition. Six bushels of Rüdersdorf quicklime weigh from 280 to 306 pounds. See KILNS.

Anhydrous lime, or, as it is commonly called, '*quicklime*,' is an amorphous solid, varying much in coherence, according to the kind of rock from which it is obtained; its specific gravity varies from 2·3 to 3. Lime is one of the most infusible bodies which we possess; it resists the highest heats of our furnaces.

When exposed to air, quicklime rapidly absorbs water and crumbles into a powder, commonly known as *slaked lime*, which is a *hydrate of lime*.

Hydrate of lime, when exposed to the air, absorbs carbonic acid, and after long exposure it is converted into a mixture of carbonate of lime and hydrate of lime in single equivalents. Hydrate of lime is but slightly soluble in water, 729 to 733 parts of that fluid dissolving only 1 part of the lime at ordinary temperatures.

Hydrate of lime is applied to numerous purposes in the arts and manufactures. It is chiefly employed in the preparation of mortar for building purposes. See MORTAR.

The pure limes, prepared from the carbonates of lime, form an imperfect mortar suitable only for dry situations. In damp buildings or in wet situations they never *set* (as the process of hardening is technically termed), but always remain in a pulpy state. General Pasley says, 'The unfitness of pure lime for the purposes of hydraulic architecture has been proved by several striking circumstances that have come under my personal observation, of which I shall only mention a few. First, a great portion of the boundary-wall of Rochester Castle having been completely undermined, nearly throughout its whole thickness, which was considerable, whilst the upper part of the same wall was left standing, I had always ascribed this remarkable breach to violence, considering it as having been the act of persons intending to destroy the wall for the sake of the stone; but on examining it more accurately after I had begun to study the subject of limes and cements, I observed that the whole of the breached part was washed by the Medway at high water, and that all the mortar of a small portion of the back part of the foot of the wall still left standing was quite soft, but that towards the ordinary high water level it became a little harder, and above that level it was perfectly sound. I observed the same process at the outer wall of Cockham Wood Fort, on the left bank of the Medway, below Chatham, of which the upper part was standing, whilst the lower part of it had been gradually ruined by the action of the river at high water destroying the mortar.' The peculiar conditions necessary to insure a good and useful mortar for building purposes, and the peculiarities of the hydraulic mortars or cements are treated of under HYDRAULIC CEMENTS and MORTAR.

LIMESTONE. (*Calcaire*, Fr.; *Kalkstein*, Ger.) A great variety of rocks contain a sufficient quantity of carbonate of lime to be called limestones.

Chalk is an earthy massive opaque variety, usually soft and without lustre, and may be regarded as a tolerably pure carbonate of lime. Carbonate of lime dissolves in 1,000 parts of water charged with carbonic acid. (*Bischof.*) Fresenius states that it dissolves in 8,834 parts of boiling water and in 10,601 parts of water at ordinary temperatures.

Carbonate of lime is found in nature more or less pure; it occurs crystallised, as in calcspar and aragonite; and also occurs as granular limestone; and in compact masses, as in common limestone, chalk, &c.

Stalactitic carbonate of lime, frequently called concretionary limestone, is formed by the infiltration of water through rocks containing lime, which is dissolved out, and as it slowly percolates the rocks into cavernous openings, the water parts with its carbonate of lime, which is deposited in zones more or less undulated, which have a fibrous structure from the crystalline character of the concretionary lime. The long fibrous pieces called stalactites show those fibres very beautifully. The stratiform masses called stalagmites exhibit a similar structure, varied only by the conditions under which they are formed. A very remarkable stalagmitic limestone found in Egypt is known as oriental alabaster.

True *Alabaster* is a sulphate of lime, but the stalagmitic carbonate is not unfrequently called by this name. See ALABASTER.

Incrusting concretionary limestones differ but little from the above. They are deposits from calcareous springs which are common in some parts of Derbyshire, Yorkshire, and other places. It is a common practice to place vegetable substances in those springs; they then become incrusted with carbonate of lime, and are sold as petrifactions, which they are not. In volcanic districts many very remarkable springs of this character exist. One of the most remarkable is at the baths of San Filippo, in Tuscany, where the water flows in almost a boiling state; carbonate of lime here appears to be held in solution by sulphuretted hydrogen, which flies off when the water issues to-day. Dr. Vegny has taken advantage of this property of the spring to obtain basso-rilievo figures of great whiteness and solidity by occasioning the lime to deposit in sulphur moulds.

Agaric mineral, Spongy limestone, Rock milk, is found at the bottom of and about lakes whose waters are impregnated with lime. The *calcareous tufa* of Derbyshire is of this character; it may be studied in every stage of formation.

Travertino, which served to construct most of the monuments in ancient Rome, appears to have been formed by the deposits of the Anio and the Solfatara of Tivoli. The temples of Pæstum, which are of extreme antiquity, have been built with a *travertino*, formed by the waters which still flow in this territory.

Compact limestone has a compact texture, usually an even surface of fracture, and dull shades of colour.

Granular limestone includes common statuary and architectural marble, and has a texture something like loaf-sugar. Under those two heads are grouped a great number of varieties.

Oolite or *roe-stone* consists of spherical grains of various sizes, from a millet seed to a pea, or even an egg.

Coarse-grained limestone. Coarse lias has been referred to this head.

Marly limestone. Lake- and fresh-water limestone formation; texture fine-grained, more or less dense; apt to crumble down in the air; colour white or pale yellow; fracture rough-grained, somewhat conchoidal; rather tenacious. Texture occasionally cavernous, with cylindrical winding cavities. This true limestone must not be confounded with lime marl, which is composed of calcareous matter and clay.

Siliceous limestone. A combination of silica and carbonate of lime, varying very much in the proportions, and sometimes passing from *cherty limestone* into *chert.* It scratches steel, and leaves a siliceous residuum after the action of muriatic acid.

Stinkstone or *Swinestone.* A carbonate of lime combined with sulphur and organic matter. It emits the smell of sulphuretted hydrogen by a blow or by friction. It occurs at Assynt, in Sutherlandshire, in Derbyshire, and some parts of Ireland.

Bituminous limestone. Limestone containing various hydrocarbon compounds, diffusing by the action of fire a bituminous odour, and becoming white when burnt.

Limestones of whatsoever kind may be referred to deposition effected by chemical change. The immense lapse of time required to form the great limestone ranges of this country can scarcely be estimated.

Oolitic limestone includes Bath stone, Portland stone, and Caen stone.

Pisolite is a variety of oolite, in which the concretions become as large as peas.

Nummulitic limestone, *Clymenia*, *Crinoidal*, or *Encrinital* limestones, &c., are so called from the fossils which the rock contains.

Shell-limestone or *Muschelkalk* has its name in the same way from its composition.

Cipolino is a granular limestone containing mica.

Majolica, a white and compact limestone.

Scaglia, a red limestone in the Alps.

See ALABASTER; CHALK; HYDRAULIC CEMENT; and MARBLE.

LIMESTONE, MAGNESIAN (*Dolomie*, Fr.; *Bitterkalk*, *Talkspath*, Ger.), is a mineral which crystallises in the rhombohedral system. Spec. grav. 2·88; scratches calc-spar; does not fall spontaneously into powder when calcined, as common limestone does. It consists of 1 equivalent of carbonate of lime = 50, associated with 1 of carbonate of magnesia = 42.

Massive magnesian limestone is yellowish-brown, cream-yellow, and yellowish-grey; brittle. It dissolves slowly and with feeble effervescence in dilute muriatic acid; whence it is called *Calcaire lent dolomie*, by the French mineralogists. Specific gravity, 2·6 to 2·7.

Near Sunderland it is found in flexible slabs. The principal range of hills composing this geological formation in England, extends from Sunderland on the north-east coast to Nottingham, and its beds are described as being about 300 feet thick on the east of the coal-field in Derbyshire, which is near its southern extremity.—H. W. B. See DOLOMITE.

LIME TREE (*Tilia Europæa*). The well-known linden tree, common to all Europe. The wood is very light-coloured, fine and close in the grain, and when properly seasoned, not liable to warp. It is much used in the manufacture of pianofortes and harps. It is made into cutting boards for curriers, shoemakers, &c., as it does not turn the knife in any direction of the grain, nor injure the edge.

Lime-tree wood is especially useful for carving, from its even texture and freedom from knots. The beautiful works of Gibbons at Hampton Court, at Windsor, and at Chatsworth, are executed in lime-tree wood, as are also the works of Rogers.

LIMNITE. A name applied to certain varieties of hydrous peroxide of iron, having the composition—$Fe^2O^3.3HO$ ($\mathbf{Fe^2O^3.3H^2O}$). Some kinds of bog iron-ore and stalactitic brown iron-ore may come under this denomination. The name is derived from λιμνή (*limnē*), a marsh.

LIMOGES ENAMELS. See Enamels.

LIMONITE. A hydrous peroxide of iron of the composition—$2Fe^{2}O.^{3}3HO$ ($\mathbf{2Fe^{2}O^{3}.3H^{2}O}$). It includes most of the bog iron-ores and the so-called brown hæmatites. The name is derived from λειμῶν (*leimōn*), a meadow. See Iron.

LINARITE. A hydrous sulphate of copper and lead, occurring in beautiful dark blue crystals at Leadhills in Lanarkshire, and at several localities in Cumberland. It takes its name from Linares in Spain.

LINDEN TREE. See Lime Tree.

LINEN. History does not state at what period of the world's existence the manufacture of cloth from flaxen material was first introduced; but from many evidences found in Egyptian mausoleums the process of weaving must have been known and practised even before the great shipbuilder laid the first planks of his famous Ark. Throughout the pages of Sacred Writ the allusions to 'fine linen,' 'broidered linen,' and the fancy styles of the fabric as they were brought out wefted with gold threads and coloured yarns, show that in those days the clothing of princes, priests, and people was largely composed of the different qualities of such material. In ancient Greece the embroidering of linen robes was delighted in as a popular pastime by the ladies of high degree, and the Romans of old were no less fond of the manufacture. But all their fancy goods were not furnished by the needle alone. Homer alludes to his famous heroine weaving pictures in the loom, and other productions similar in pattern to the damask of modern days were worked by the shuttle in ancient Greece.

The use of linen was pretty general in the higher circles of society in the British isles at a very remote period; but all the finer varieties of the fabric were imported from the continent of Europe. Woollen goods formed the principal material for inner as well as outside clothing of the people on both sides the Tweed in the fifth century; but even then linen was considered an essential requisite for special purposes, and particularly for wrapping the bodies of the dead. Weaving was cultivated by the more skilful peasants for a long period afterwards; but it does not appear that any high order of work had been produced until the reign of Henry III., when a number of Flemings brought over by that monarch settled in Sussex and introduced a very superior make of linen. We have only slight allusions in after history respecting the progress of the trade either in England, Scotland, or Ireland. The yarns, at least those of the upper counts used in Sussex and Lancashire were imported from Holland, Flanders and Ireland. A high authority—Leland—in alluding to the Liverpool trade says: 'Irysh merchantes doe cum muche heyre withe linnen yarne, the whiche Manchester men doe bye.' King William tried to give greater impulse to the trade in England, but somehow the pride of the people in manufacturing districts to uphold woollen, 'the noble and national fabric,' stood in the way; and while royal patronage did immense good in Scotland and Ireland, it had little effect in England. Sam Homespun's calculations relative to the value of a single acre's produce of flax when spun and woven were made in 1742, and given at length in the leading magazine of that day; but marvellous as they were, so far as referred to the profits which might be made in the linen manufacture, the subject was not taken up in the spirit intended by that writer. Shortly afterwards the discoveries of Hargreaves, Arkwright, and others, and the enterprise created thereby in the cotton trade opened up new avenues in the manufacturing world of England; farmers there gradually decreased the area of flax culture; and, except in few localities, linen weaving no longer occupied any large space in the republic of labour.

In the meantime very great progress had been maintained in the manufacture of linen in Scotland and Ireland. Bounties and other artificial stimulants were freely administered by the State; a Board of Trustees for Scotland sat in Edinburgh, and local influence was largely used to give effect to the movement for improving the manufacture. The Bounty Act became law in 1742, and in the course of that year 4,431,500 yards of linen were stamped by the inspectors appointed for that purpose. Twelve years afterwards, and when the bounty system was given up, the turn out of goods had increased to 8,914,400 yards; in 1800, 24,236,630 yards were produced and stamped by the inspectors; and in 1822 there was a total of 36,268,530 yards of linen made in Scotland. The introduction of flax spinning by mechanical power and of weaving linen on the steam-loom principle, made a remarkable change in the Scotch trade. Dundee had long been the great centre of the flaxen manufactures, and of late years it has taken the lead in the Jute trade. Twenty-five years ago the imports of Jute into Dundee were 12,500 cwts.; in 1863, 46,900 cwts. were landed there; and of the total import of 2,583,842 cwts. for the six months ending June 30, 1874, a large proportion went to Dundee. The capital employed in that town and neighbourhood in the flax and Jute trades cannot at present be under five and a half millions sterling.

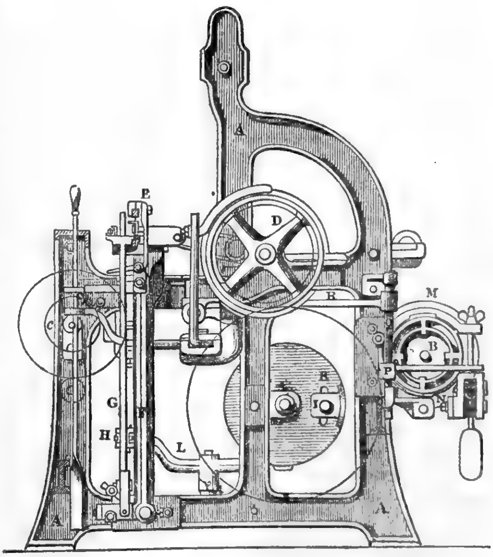
Ireland's linen trade was its great sheet anchor in times the records of which have been lost in the mist of ages. Long before the reign of William the Conqueror Irish linen occupied a large space among the wares exposed for sale at the great fairs of England. The looms used in the make of goods were, however, of very primitive construction; and, until the semi-regal reign of Wentworth, Earl of Strafford, no effort had been made to improve those machines. In course of a tour through Ulster that viceroy saw that much was required to place the Irish trade on something like equality with their French and Dutch competitors. He had already, by importing superior flax seed and giving it at cost price to the farmers succeeded in creating, as it were, a higher class of fibre, and at considerable cost he brought over from Holland some hundreds of looms, all of which he distributed among the more ambitious class of weavers.

The trade at that time may be said to have been a local one, as the total annual value of linen exports did not exceed an average of 10,000*l.*, and that aggregate had not increased in any great degree when the first batch of Huguenot exiles landed in Ireland. How much the Prince of Orange contributed towards the establishment of a new system of flaxen manufacture has still to be acknowledged by the people of that country. He was the warm friend of the Gallic fugitives, and his kindly feeling towards those victims of persecution led to the most important results in all departments of the Irish trade. We have alluded to the value of exports in 1690. In 1706 the quantity of linen sent from Ireland was 530,900 yards, valued at 10*d.* a yard. In 1726 there were 4,368,396 yards exported; and in 1766 the account had ran up to 17,892,000 yards, while the average value had arisen to 15*d.* a yard. Forty years afterwards, Ireland exported 43,534,000 yards of linen, and in 1836 the export was 60,000,000 yards.

Up to this time, and for a great many years afterwards, all the linen produced in Ireland had been woven by hand. Considerable impulse was given to the trade by the introduction, a few years before, of flax-spinning by steam-power. Still, although flaxen goods were largely produced in Kirkcaldy and Dundee on the power-loom principle, no attempt had been made to bring out the new weaving-machine in Ireland. We here give two figures of the loom as constructed some years ago for the working of heavy linen.

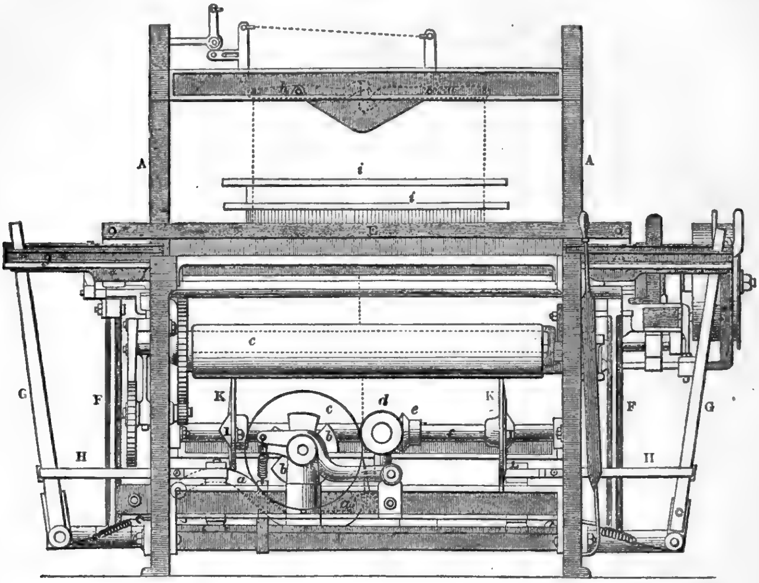
Flax Weaving Loom for Heavy Fabrics.—A A A, *figs.* 1390, 1391, frame of loom; B, beam on which the yarn for warp is wound; C, cloth-receiving beam; D, driving pulleys and fly-wheel; E, hand rail for supporting the reed; F, swords of supports of going part; G, picking sticks for driving the shuttle; H, leather straps for connecting the picking sticks with their actuating levers L; M, N, jaws of a clamp to cause the retaining friction on the collars of the beam B, by which friction the quantity of weft is regulated; O, end of lever, bearing the weight by which the jaws are brought together; P, lever, keyed at one end to the upright shaft Q, and connected with the other to the fulcrum of the weighted lever O; R, lever, one end of which is also keyed to the upright shaft Q, and the other is provided with a wood sole, and is pressed by a strong spring against the yarn wound upon the beam B. It will be seen that, as the yarn is taken off the beam B, and its diameter consequently reduced, the lever P moves the fulcrum of the weighted lever O, and thus regulates the pressure upon the clamps M and N, causing an equal tension upon the yarn from the full to the empty beam; *a*, treddles, actuated by the cams *b*, driven by the wheels *c*, *d*, *e*, from the

1390



picking shaft *f*; *g g*, shuttle-boxes at each end of the going part; *h h*, arrangement of levers to conduct equally each end of the gears *i i*. This loom has also, in addition to the ordinary stopping arrangement connected with the shuttle, one also for relaxing the reed in case the shuttle should be arrested in its course across the warp, whereby the danger, ordinarily incurred by that accident, of breaking many threads in the warp is avoided; it will also be seen that the bands called picking bands are superseded by the ends of the picking levers striking the shuttle direct; thus, by these improvements, drills are currently woven in this loom at the rate of 120 to 130 picks per minute.

1391



About a dozen years since extensive trials were made to adapt the power-loom to the weaving of light linen fabrics. Previously it had been found that while coarse and strong flax fabrics, such as those made at Dundee, Arbroath, &c., in Scotland, and the drills made at Barnsley, could be produced by power as well and more cheaply than by hand, yet that the lighter fabrics, such as shirtings, cambrics, lawns, &c., would not bear the strain of the power-loom, or, at all events, that to make them of as good appearance as by the hand-loom the manufacturer required to employ a dearer article of yarn, and so found that he could not compete with his neighbours who had hand-loom weavers.

Irish manufacturers were for a long time very hard to convince that, except for the production of sets, say from 8^{00} to 12^{00}, the steam-driven loom was not likely to be worked successfully. But at length the increasing demand for linen, and the difficulty of procuring hands to work on the ordinary loom, forced capitalists to adopt the new mode of production, and rapidly did the system extend when it was found not only to equal, but far exceed that which had been expected from it. Hand-loom weaving, in coarse, heavy linens, was a labour that required more than average strength, and yet, when it was maintained for fourteen hours a day, the operator did not earn as much as a factory worker can now realise by his ten hours' labour. Many linen weavers, as demand for hands increased in other sections of industry, forsook the loom, and the only alternative manufacturers had was the substitution of the iron machine and the steam-engine for the old wooden loom and the hand-weaver.

In 1857 there were only 30 power-looms at work on linen weaving in Ireland, in 1860 there were 4,000, in 1866, 10,000, and in 1872, about 15,500 power-looms were engaged in the trade. Some of these machines work up to 16^{00}. In one factory an 18^{00} linen has been produced by the steam loom, but such high sets can hardly be made with profit. Damasks, diapers, and cambric handkerchiefs, are brought out in the best style, of course, up to certain sets on the same principle, but the upper class of work can only be rightly done by hand. In fact, the practical limit to steam production of linens has been found to be the weaving of a 16^{00}-web; any fabric above that 'set' cannot well be brought out by 'power,' so as to compete with the hand-loom work.

The improvements recently effected in the make of the steam loom have nearly all been favourable to the operatives. Stronger and better fitted-up machines are now seen in factories; for instance, a loom which a dozen years ago, and constructed for a certain class of work, weighed 15 to 16 cwts., would now be brought out so much heavier as to weigh 17 to 18 cwts. One effect of the improvement in gearing is to give the workpeople greater facility of production; they get through their labour with more ease, and the quality of cloth is decidedly better. In the last case, however, we must add that the superior class of yarns now thrown off the spindles has had much to do with the order of fabric made in 1874, compared with that brought out in 1863. And while thus alluding to the improvements in machinery, we must not forget to add that the better mode of ventilation in mills, the care taken as to sanitary regulations and the regularity of labour, have been producing a very gratifying change on the physical aspect of the people connected with public works. Contrasted with the appearance of the hand-loom or factory weaver of half a century since, that of his successor in the present day shows a marvellous advance in social position as well as in bodily stamina.

Exports of Linen, 1872.

Linen Yarn:	lbs.	£
To Norway	266,260	25,655
„ Denmark	768,577	72,791
„ Germany	6,327,028	624,499
„ Holland	4,538,841	273,322
„ Belgium	986,078	97,465
„ France	1,677,361	126,700
„ Spain and Canaries	11,882,108	650,053
„ Italy	2,110,300	140,579
„ Egypt	300,630	20,069
„ United States: Atlantic	1,617,946	53,317
„ Other countries	711,922	47,621
Total	31,187,051	2,131,071

Linen Piece Goods—Plain, Unbleached, or Bleached:	yards	£
To Sweden	1,214,426	36,471
„ Germany	6,532,256	266,184
„ Holland	1,000,617	42,779
„ France	4,429,502	176.485
„ Portugal, Azores, and Madeira	1,559,740	48,341
„ Spain and Canaries	2,397,794	139,333
„ Italy	2,556,070	126,215
„ Turkey Proper	1,470,290	45,226
„ Egypt	1,527,060	49,437
„ United States: Atlantic	115,462.840	3,526,584
„ „ „ Pacific	1,412,340	29,942
„ Foreign West Indies	37,410,503	988,736
„ Mexico	2,367,500	79,406
„ United States of Colombia (New Granada)	6,268,739	204,827
„ Venezuela	1,671,532	43,899
„ Peru	1,833,490	51,232
„ Chili	2,248,320	70,604
„ Brazil	9,977,789	284,060
„ Uruguay	1,260,500	36,089
„ Argentine Republic	4,900,400	139,983
„ British Possessions in South Africa	1,627,027	61,486
„ Hong Kong	723,539	30,316
„ Australia	7,613,280	255,656
„ British North America	5,443,111	161,265
„ British West Indies and British Guiana	4,098,804	100,988
„ Other countries	6,830,829	247,294
Total	233,838,338	7,241,338

Checked, Printed, or Dyed, and Damasks and Diapers:	yards	£
To France	324,680	12,839
„ United States: Atlantic	1,390,020	54,316
„ „ „ Pacific	2,500	61
„ Foreign West Indies	2,608,341	65,769
„ Mexico	450,400	12,351
„ United States of Colombia (New Granada)	454,746	12,683
„ Brazil	158,900	7,258
„ Argentine Republic	97,260	3,820
„ Australia	619,100	20,316
„ British North America	102,409	3,358
„ British West Indies and British Guiana	320,180	8,838
„ Other countries	869,404	31,127
Total	7,397,940	233,736
Sail-cloth and Sails:	yards	£
To Norway	321,652	25,240
„ Denmark	247,788	14,886
„ Germany	599,660	36,637
„ Turkey Proper	130,920	7,637
„ United States: Atlantic	323,646	16,653
„ „ „ Pacific	12,300	587
„ Brazil	121,306	7,132
„ Argentine Republic	50,370	2,505
„ Channel Islands	68,350	3,305
„ British Possessions in South Africa	179,543	9,909
„ British India, Bengal, and Burmah	110,600	6,404
„ Hong Kong	101,110	6,919
„ Australia	191,550	11,589
„ British North America	702,434	41,713
„ British West Indies and British Guiana	66,490	3,955
„ Other countries	545,407	30,291
Total	3,783,126	255,291
Thread for Sewing:	lbs.	£
To Russia	91,875	11,488
„ Sweden	75,182	10,247
„ Germany	247,467	31,057
„ Holland	85,765	11,594
„ Spain and Canaries	87,326	8,392
„ Italy	28,054	3,906
„ Austrian Territories	72,845	9,647
„ Turkey Proper	76,089	7,976
„ United States: Atlantic	1,296,823	162,189
„ „ „ Pacific	1,020	144
„ Foreign West Indies	52,018	3,991
„ Brazil	48,200	5,365
„ British North America	226,222	24,214
„ Other countries	252,846	27,357
Total	2,641,732	317,566
Manufactures unenumerated:		£
To Russia	...	12,902
„ Germany	...	40,193
„ Holland	...	12,426
„ Belgium	...	16,514
„ France	...	18,744
Carried forward	...	100,779

	yards	£
Brought forward	...	100,779
To Portugal and Madeira	...	2,750
" Spain and Canaries	...	5,620
" Italy	...	5,159
" United States: Atlantic	...	13,051
" " " Pacific	...	35
" Foreign West Indies	...	14,111
" United States of Colombia (New Granada)	...	4,632
" Brazil	...	3,909
" Argentine Republic	...	4,488
" Australia	...	13,018
" British North America	...	6,379
" Other countries	...	33,828
Total		207,759

LINNÆITE. A sulphide of cobalt, named after the Swedish naturalist, Linné (Linnæus). See COBALT.

LINSEED. (*Graine de lin*, Fr.; *Leinsame*, Ger.) . The seed of the flax, *Linum usitatissimum*, which is indigenous to our islands, and is cultivated extensively in this and other countries for its seed, and for *flax*. Linseed contains in its dry state, 11·265 of oil; 0·146 of wax; 2·4808 of a soft resin; 0·550 of a colouring resinous matter; 0·926 of a yellowish substance analogous to tannin; 6·154 of gum; 15·12 of vegetable mucilage; 1·48 of starch; 2·932 of gluten; 2·782 of albumine; 10·884 of saccharine extractive; 44·382 of envelopes, including some vegetable mucilage. It contains also free acetic acid; some acetate, sulphate, and muriate of potash, phosphate and sulphate of lime; phosphate of magnesia; and silica.

LINSEED OIL is obtained from linseed by first bruising the seeds, grinding them, and subjecting them to violent pressure, either by means of wedges, or of the hydraulic or screw press. Cold drawn linseed oil is obtained cold, and is paler coloured, less odorous, and has less taste than that which is obtained when heat is applied.

It is usual to employ a steam heat of about 200° Fahr. By cold expression the seeds yield about 20 per cent., while by the aid of heat nearly 27 per cent. of oil can be obtained. The ultimate composition of linseed oil is carbon 76·014, hydrogen 11·351, and oxygen 12·635; its proximate constituents being oleic and margaric acids, and glycerine. Linseed oil is much used as a vehicle for colours by the painter. If linseed oil is exposed in a thin coat to the air it absorbs oxygen and becomes tenacious. and in many respects like caoutchouc: upon this property mainly depends its use in the arts. To secure this more readily a drying process is adopted, which must be described.

When linseed oil is carefully agitated with acetate of lead (tribasic acetate of lead), and the mixture allowed to clear by settling, a copious white cloudy precipitate forms, containing oxide of lead, whilst the raw oil is converted into a drying oil of a pale straw colour, forming an excellent varnish, which, when applied in thin layers, dries perfectly in twenty-four hours. It contains from four to five per cent. of oxide of lead in solution. The following proportions appear to be the most advantageous for its preparation:—

In a bottle containing 4½ pints of rain water, 18 ounces of neutral acetate of lead are placed, and when the solution is complete, 18 ounces of litharge in a very fine powder are added; the whole is then allowed to stand in a moderately warm place, frequently agitating it to assist the solution of the litharge. This solution may be considered as complete when no more small scales are apparent. The deposit of a shining white colour (sexbasic acetate of lead) may be separated by filtration. This conversion of the neutral acetate of lead into vinegar of lead, by means of litharge and water, is effected in about a quarter of an hour, if the mixture be heated to ebullition. When heat is not applied, the process will usually take three or four days. The solution of vinegar of lead, or tribasic acetate of lead, thus formed, is sufficient for the preparation of 22 lbs. of drying oil. For this purpose, the solution is diluted with an equal volume of rain-water, and to it is gradually added, with constant agitation, 22 lbs. of oil, with which 18 ounces of litharge have previously been mixed.

When the points of contact between the lead solution and the oil have been frequently renewed by agitation of the mixture three or four times a day, and the mixture allowed to settle in a warm place, the limpid straw-coloured oil rises to the surface, leaving a copious whitish deposit. The watery solution rendered clear by filtration, contains intact all the acetate of lead first employed, and may be used in the next operation, after the addition to it as before of 18 ounces of litharge.

By filtration through paper or cotton the oil may be obtained as limpid as water, and by exposure to the light of the sun it may also be bleached.

Should a drying oil be required absolutely free from lead, it may be obtained by the addition of dilute sulphuric acid to the above, when, on being allowed to stand, a deposit of sulphate of lead will take place, and the clear oil may be obtained free from all trace of lead.

Linseed oil was at one time much used in the preparation of a liniment, which, as it is one of the very best possible applications to a burnt surface, cannot be too generally known. *If equal parts of limewater and linseed oil* are agitated together, they form a thick liniment, which may be applied to the burn with a brush or feather. It relieves at once from pain, and forming a pellicle, protects the abraded parts from the air. The *Linimentum calcis* of the Pharmacopœia is equal parts of limewater and olive oil; this is a more elegant, but a less effective preparation. *See* OIL.

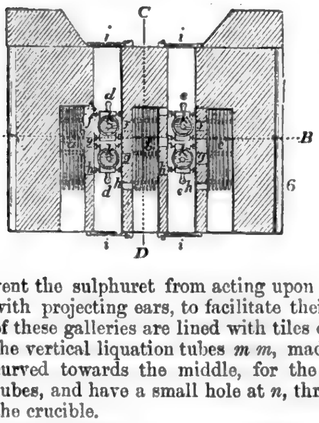
LINT *for Surgery*, was formerly prepared by scraping up linen by the hand; the preparation of it, however, has been made the subject of a patent by Mr. Thomas Ross, which consists in the employment of peculiarly constructed scrapers for abrading the surface of the linen cloth, and producing a pile or nap upon it. The scrapers are worked by a rotary motion.

Instead of rotary scrapers, a reciprocating pendulous movement is sometimes applied to a single scraper. Chisel-formed blades are claimed by the patentee as scrapers for raising the pile, by working with the bevel edges forwards, so as to scrape and not to cut the fabric. He has in the rotary form a ledge or bed concentric with the axis of the scraper, which he also claims; both of which seem to be serviceable. Several kinds of lint-making machines are now employed, but as they all partake more or less the above principles they do not require description.

LIQUATION (Eng. and Fr.; *Saigerung*, Ger.) is the process of sweating out, by a regulated heat, from an alloy a more easily fusible metal from the interstices of a metal which is more difficult of fusion. Lead and antimony are the metals most commonly subjected to liquation: lead for the purpose of removing by its superior affinity the silver present in any complex alloy; antimony as an easy means of separating it from its combinations in the ores.

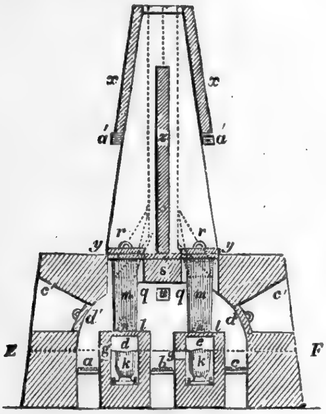
Figs. 1392, 1393, 1394, represent the celebrated antimonial liquation furnaces of Malbosc, in the department of Ardèche, in France. *Fig.* 1392 is a ground plan taken at the level of the draught holes *g g*, *fig.* 1393, and of the dotted line E F; *fig.* 1393 is a vertical section through the dotted line A B, of *fig.* 1392; and *fig* 1394 is a vertical section through the dotted line C D of *fig.* 1392. In the three figures, the same letters denote like objects. *a*, *b*, *c*, are three grates upon the same level above the floor of the works, 4½ feet long, by 10½ inches broad; between which are two rectangular galleries, *d e*, which pass transversely through the whole furnace, and lie at a level of 12 inches above the ground. They are separated by two walls from the three fire-places. The walls have three openings, *f g h*, alternately placed for the flames to play through. The ends of these galleries are shut in with iron doors *i i*, containing peep-holes. In each gallery are two conical cast-iron crucibles *k k*, into which the *eliquating* sulphuret of antimony drops. Their height is from 12 to 14 inches; the width of the mouth is 10 inches, that of the bottom is 6, and the thickness four-tenths of an inch. They are coated over with fire-clay, to prevent the sulphuret from acting upon them; and they stand upon cast-iron pedestals with projecting ears, to facilitate their removal from the gallery or platform. Both of these galleries are lined with tiles of fire-clay *l l*, which also serve as supports to the vertical liquation tubes *m m*, made of the same clay. The tiles are somewhat curved towards the middle, for the purpose of receiving the lower ends of these tubes, and have a small hole at *n*, through which the liquid sulphuret flows down into the crucible.

1392



The liquation tubes are conical, the internal diameter at top being 10 inches, at bottom 8; the length fully 40 inches, and the thickness six-tenths of an inch. They have at their lower ends notches or slits, *o*, *fig.* 1394, from 3 to 5 inches long, which look outwards, to make them accessible from the front and back part of the furnaces through small conical openings *p p*, in the walls. These are closed during the operation with clay stoppers, and are opened only when the gangue, rubbish, and cinders are to be raked out. The liquation-tubes pass across the arch of the furnace, *q q*, the space of the arch being wider than the tubes; they are shut in at top with fire-covers *r r*. *s s*, the middle part of the arch, immediately under the middle grate, is barrel-shaped, so that both arches are abutted together. The flames, after playing round about the sides of the liquation-tubes, pass off through three openings and flues into the chimney *t*, about 13 feet high; *u*, being the one opening, and *v*, the two others, which are provided with register-plates. In front of the furnace is a smoke-flue, *w*, to carry off the sulphurous vapours exhaled during the clearing-out of the rubbish and slag; another, *x*, begins over *y y*, at the top of the tubes; a wall, *z*, separates the smoke-flue into halves, so that the workmen upon the one side may not be incommoded by the fumes of the other. This wall connects at the same time the front flue, *w*, with the chimney *t*. *a a'* and *b' b'* are iron and wooden bearer beams and rods for strengthening the smoke-flue. *c' c'* are arches upon both sides of the furnace, which become narrower from without inwards, and are closed with well-fitted plates *d' d'*. They serve in particular circumstances to allow the interior to be inspected, and to see if either of the liquation-furnaces be out of order. Each tube is charged with 500 lbs. of antimonial ore, previously warmed; in a short time the sulphuret of antimony begins to flow off. When the liquation ceases, the cinders are raked out by the side openings, and the tubes are charged afresh. The luted iron crucibles are allowed to become three-fourths full, are then drawn out from the galleries, left to cool, and emptied, The ingot weighs about 85 lbs. The average duration of the tube is 3 weeks. This plan is proved to be an exceedingly economical one.

1393



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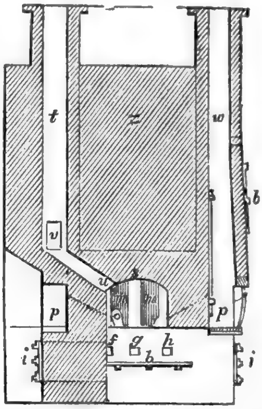

LIQUEURS, LIQUORISTE. Names given by the French, and adopted into our language, to denote certain aromatic alcoholic cordials, and to the manufacturer of them.

Some liqueurs are prepared by infusing the woods, fruits, or flowers, in either water or alcohol, and adding thereto sugar and colouring matter. Others are distilled from the flavouring agents.

Many of the liqueurs are of very compound character, as the following recipes will show:—

Martinique Noyeau.—Put into a stone jar,

Preserved guavas and their syrup, or the jelly of that fruit	½ lb.
Oil of sweet almonds	1 oz.
Sweet almonds, beaten fine	1 lb.
Bitter „ „	1
Preserved ginger and its syrup	2
Cinnamon and cloves (bruised) of each	½
Nutmeg and Pimento „ „	¼
Jamaica ginger „	½
Candied lemon and citron, of each	1
White sugar-candy (powdered)	14
Proof spirit of wine	5 quarts.

Beat the oil with a little brandy, and mix it with the almonds, when beaten to a paste with orange-flower water. Stop up the jar securely, and let it remain in a warm room, or in the sun, shaking it often, for a fortnight. Keep it in the jar for twelve or fifteen months; then strain it, and filter repeatedly until it is as clear as spring water. Rinse phials or half-pint bottles, with any white wine, drain them and fill. Cork and seal well. In six months it will be fit for use, if required, but will improve greatly by age.—*Robinson.*

Tears of the Widow of Malabar.—To ten pounds of spirit (pale brandy), add 4 pounds of white sugar, and 4 pints of water, adding 4 drachms of powdered cinnamon, 48 grains of cloves, and the same quantity of mace; colour with caramel.

The Sighs of Love.—Spirit, water, and sugar as above. Perfume with otto of roses, and slightly colour with cochineal.

Absinthe.—Take of the tops of wormwood, 4 pounds, root of angelica, calamus aromaticus, aniseed, leaves of dittany, of each, 1 oz.; alcohol, four gallons.

Macerate these substances during eight days, add a little water, and distil by a gentle fire until two gallons are obtained. This is reduced to a proof spirit, and a few drops of the oil of aniseed added. See ABSINTHE.

These forms exemplify the character of all kinds of liqueurs. They are coloured *yellow* by the colouring matter of carthamus; *fawn* is produced by caramel; *red,* by cochineal; *violet,* by litmus, or archil; *blue,* by the sulphate of indigo; *green,* by mixing the blue and the yellow together.

Ratafia is the generic name, in France, of *liqueurs* compounded with alcohol, sugar, and the odoriferous or flavouring principles of vegetables. Bruised cherries with their stones are infused in spirit of wine to make the ratafia of Grenoble *de Teyssère.* The liquor being boiled and filtered, is flavoured, when cold, with spirit of *noyeau,* made by distilling water off the bruised bitter kernels of apricots, and mixing it with alcohol. Syrup of bay laurel and galango are also added.

LIQUIDAMBAR. A balsam obtained from the *Liquidambar styraciflua,* a native of North America.

LIQUID STORAX. The produce of the *Liquidambar orientale.*

LIQUORICE (*Glycyrrhiza glabra;* from γλυκὺς, sweet, and ῥίζα, a root. The root only is employed; these roots are thick, long, and running deep in the ground.

Besides the use of liquoric roots in medicine, they are also employed in brewing, and are pretty extensively grown for these purposes in some parts of England. Liquorice requires a rich, deep, dry, sandy soil, which, previous to forming a new plantation, should be trenched to the depth of about 3 feet and a liberal amount of manure regularly mixed with the earth in trenching. The plants which are procured by slipping them from those in old plantations are, either in February or March, dibbled in rows 3 feet apart, and from 18 inches to 2 feet in the row. They require three summers' growth before being fit for use, when the roots are obtained by retrenching the whole, and they are then stored in sand for their preservation until required.—*Peter Lawson.*

Large quantities of extract of liquorice-root are imported into this country under the name of *Spanish* or *Italian juice,* according as it comes from one peninsula or the other. Whilst the Spanish juice is yielded by *G. glabra,* it is said that the Italian liquorice is prepared from *G. echinata.* Liquorice juice contains an uncrystallisable sugar called *Glycyrrhizin* or *Liquorice Sugar.*

LIROCONITE. A hydrous arsenate of copper, occurring in sky-blue crystals. It was formerly found in some of the Cornish copper-mines.

LITHARGE (Eng. and Fr.; *Glätte,* Ger.) is the fused yellow protoxide of lead, which on cooling passes into a mass consisting of small six-sided plates, of a reddish yellow colour and semi-transparent. It generally contains more or less red lead, whence the variations of its colour, and carbonic acid, especially when it has been exposed to the air for some time. For its mode of preparation, see LEAD, and SILVER.

LITHIA is a simple earthy or alkaline substance, discovered in the minerals called petalite and triphane. It is white, very caustic, reddens litmus and red cabbage, and saturates acid with great facility. When exposed to the air it attracts humidity and carbonic acid. It is more soluble in water than baryta, and has such a strong affinity for it as to be obtained only in the state of a hydrate. It forms neutral salts with all the acids. It is most remarkable for its power of acting upon or corroding platinum. This earth is now used medicinally.

The following interesting account of a new source of lithium is from the address of Sir Charles Lyell at the Bath meeting of the British Association. After stating that Professor Roscoe of Manchester had detected the chloride of lithium in the Bath waters, Sir Charles Lyell proceeds:—

'While I was pursuing my inquiries respecting the Bath waters, I learned casually that a hot spring had been discovered at a great depth in a copper mine, near Redruth in Cornwall, having about as high a temperature as that of the Bath waters, and of which, strange to say, no account has yet been published. It seems that, in the year 1839, a level was driven from an old shaft, so as to intersect a rich copper lode at a depth of 1,350 feet from the surface. This lode or metalliferous fissure occurred in what was formerly called the United Mines, and which have since been named the Clifford Amalgamated Mines. Through the contents of the lode a powerful spring of hot water was observed to rise, which has continued to flow with undiminished strength ever since. At my request Mr. Horton Davey, of Redruth, had the kindness to send up to London many gallons of this water, which have been analysed by Professor William Allen Miller, F.R.S., who finds that the quantity of solid matter is so great as to exceed by more than four times the proportion of that yielded by the Bath waters. Its composition is also in many respects very different; for it contains but little sulphate of lime, and is almost free from the salts of magnesium. It is rich in the chlorides of calcium and sodium, and it contains one of the new metals, *Cæsium*, never before detected in any mineral spring in England; but its peculiar characteristic is the extraordinary abundance of lithium, of which a mere trace had been found by Professor Roscoe in the Bath waters; whereas, in this Cornish hot spring, this metal constitutes no less than a twenty-sixth part of the whole of the solid contents, which, as before stated, are so voluminous. When Professor Miller exposed some of these contents to the test of spectrum analysis, he gave me an opportunity of seeing the beautiful bright crimson line which the lithium produces in the spectrum.

'Lithium was first made known in 1817 by Arfvedsen, who extracted it from petalite; and it was believed to be extremely rare, until Bunsen and Kirchhoff, in 1860, by means of the spectrum analysis, showed that it was a most widely-diffused substance, existing in minute quantities in almost all mineral waters and in the sea, as well as in milk, human blood, and the ashes of some plants. It has already been used in medicine, and we may therefore hope that now that it is obtainable in large quantities, and at a much cheaper rate than before the Huel Clifford hot spring was analysed, it may become of high value. According to a rough estimate, which has been sent to me by Mr. Davey, the Huel Clifford spring yields no less thon 250 gallons per minute, which is almost equal to the discharge of the King's Bath, or chief spring of this city. As to the gases emitted, they are the same as those of the Bath water, namely, carbonic acid, oxygen, and nitrogen.'

Mr. Warington Smyth, who had already visited the Huel Clifford lode in 1855, re-examined it shortly before this meeting, chiefly with the view of replying to several queries which Sir Charles Lyell put to him; and, in spite of the stifling heat, ascertained the geological structure of the lode, and the exact temperature of the water. This last he found to be 122° Fahr. at the depth of 1,350 feet; but he scarcely doubts that the thermometer would stand two or three degrees higher at a distance of 200 feet to the eastward, where the water is known to gush up more freely. The Huel Clifford lode is a fissure varying in width from 6 to 12 feet, one wall consisting of elvan or porphyritic granite, and the other of killas or clay-slate. Along the line of the rent, which runs east and west, there has been a slight throw or shift of the rocks. The vein-stuff is chiefly formed of cellular pyrites of copper and iron, the porous nature of which allows the hot water to percolate freely through it. It seems, however, that in the continuation upwards of the same fissure, little or no metalliferous ore was deposited, but, in its place, quartz and other impermeable substances, which obstructed the course of the hot spring so as to prevent its flowing out on the surface of the country.

Huel Clifford Amalgamated Mine, having ceased to pay the adventurers, was stopped working in 1872. It is now (1874) full of water, and in all probability it will never again be opened.

A similar hot spring has been discovered in Huel Seton Mine near Camborne, Cornwall. The waters issue, at the rate of 50 gallons per minute, from the eastern fore-breast of the 160-fathom level, at a temperature of 92° Fahr. This water has been analysed with the greatest care by Mr. John Arthur Phillips, and found to contain a larger quantity of lithium than the Huel Clifford spring. Mr. J. A. Phillips communicated the results of his examination to the Royal Society; from which communication the following analysis is extracted:—

	Grains per gallon
Calcium carbonate	7·03
Ferrous carbonate	0·33
Manganous carbonate	trace
Calcium sulphate	2·11
Cupric chloride	minute trace
Calcium chloride	475·54
Carried forward	485·06

	Grains per gallon
Brought forward	485·06
Magnesium chloride	11·80
Aluminum chloride	63·09
Potassium chloride	6·30
Sodium chloride	407·47
Lithium chloride	33·74
Potassium bromide	trace
Potassium silicate	5·03
Nitric acid	trace
Ammonia	trace
Total	1012·49

LITHIUM is the metallic basis of lithia; the latter substance consists of 100 of metal and 123 of oxygen. Lithium is the lightest known solid, its specific gravity being 0·59. Its atomic weight (7) is lower than that of any other element, excepting hydrogen. Lithium is not of any use in the arts. See LITHIA.

LITHOFRACTEUR. See EXPLOSIVE AGENTS.

LITHOGRAPHIC PRESS. The lithographic press in common use has long been regarded as a very inadequate machine. The amount of manual power required to work it, and the slow speed at which, under the most favourable circumstances, copies can be produced, disables lithography in its competition with letter-press. A career of brilliant success has attended the efforts of scientific men towards speed and success in this latter branch of the art; and the present printing-machines surpass the hand-press somewhat in the same ratio as does our express-speed the jog-trot of our forefathers. The engravings annexed, *figs.* 1395, 1396, will serve to illustrate Messrs. Napier and Sons' improvements upon the lithographic press. The machine is arranged to be driven by steam-power; has belts, 'crossed' and 'open,' supposed to be in connection with the engine, and to rank upon the pulleys, A, B, C. The crank-pulley, B, is fixed on the screw-spindle, D, and the other two work loose, or 'dead,' on the same spindle; these bands, with their striking-forks, *a*, are arranged so as to be brought alternately upon the fixed pulley, B, and thus a reversing-motion is given to the screw. The nut in which the screw works is fixed to a cross-piece, E, which braces the side-frames, F F, together at bottom, while the bar, G, performs the same office at top; the scraper-box, H, is sustained between these frames at bearings, I, and is so fitted as to work freely. To support the frames and scraper-box independent of the screw and maintain them in position, allowing freedom of action, the rollers, J J, are provided, which run in the planed recesses, K, along the top of the main standards, L.

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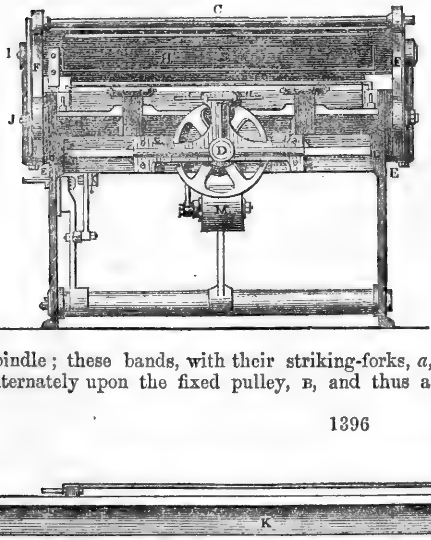

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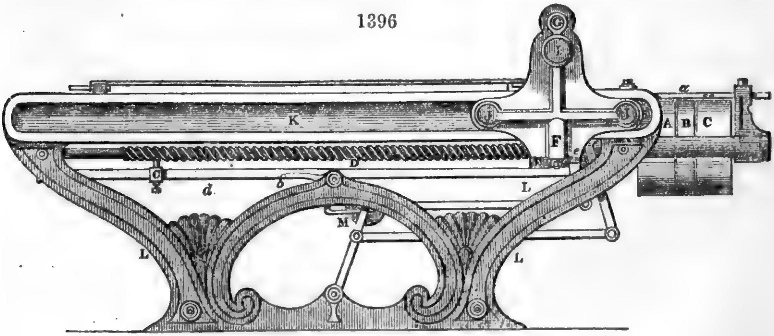


The machine is shown with its tympan down, ready for starting; this is effected by pressing lightly upon the lever, *b*, which raises a catch, and allows the weight, M, to descend in the direction of its present inclination, and act upon the connections with the striking-forks, so as to bring one of the bands upon the fast pulley, B, and make the scraper and its frames move forward. The return is caused by the frame, F, coming in contact with a stop, C, which, yielding, acts upon the striking-forks by its bar, *d*, upon which it may be adjusted to give the travel required. On the return being accomplished, the machine stops itself by a striking action against stop *e*, the catch, *b*, falling in to prevent the weight descending to its full throw, and thus retaining the two bands upon the two dead pulleys, A, C, while the machine is prepared for another impression.

The action of the scraper is peculiar and novel: it is balanced so that its tendency is to remain slightly raised, but in its forward movement, and at the point desired, it is made to descend by a stop fixed upon the top of the main standard, L, into a position vertical, or nearly so, in which position it is retained by its own onward progress against strong abutments projecting from the frames, F; on the return it resumes its raised position, and passes back without impediment. The scraper may be adjusted to give the pressure desired, or the table on which the stone is placed regulated by screws.

The advantages embodied in this machine will be at once recognised by those interested. The pulling down of the scraper, and the labour and inconvenience attendant upon that operation, are entirely superseded by the simple and effectual valve-like movement just explained, which forms the groundwork of this combination, although it will alike apply to the press-work by hand, and is the most striking novelty in the machine.

LITHOGRAPHY. Though this subject belongs rather to the arts of taste and design than to productive manufactures, its chemical principles fall within the province of this Dictionary.

The term *lithography* is derived from λίθος, *a stone*, and γραφή, *writing*, and designates the art of throwing off impressions upon paper of figures and writing previously traced upon stone. The processes of this art are founded—

1. Upon the adhesion to a grained or smoothly-polished limestone of an encaustic fat which forms the lines or traces.

2. Upon the power acquired by the parts penetrated by this encaustic of attracting to themselves, and becoming covered with, a printer's ink having linseed-oil for its basis.

3. Upon the interposition of a film of water, which prevents the adhesion of the ink in all the parts of the surface of the stone not impregnated with the encaustic.

4. Lastly, upon a pressure applied to the stone, such as to transfer to paper the greater part of the ink which covers the greasy tracings or drawings of the encaustic.

The lithographic stones of the best quality are still procured from the quarry of Solenhofen, a village at no great distance from Munich, where this mode of printing had its birth. They resemble in their aspect the yellowish-white lias of Bath, but their geological place is much higher than the lias. Abundant quarries of these fine-grained limestones occur in the county of Pappenheim, along the banks of the Danube, presenting slabs of every required degree of thickness, parted by regular seams, and ready for removal with very little violence. The good quality of a lithographic stone is generally denoted by the following characters: its hue is of a yellowish-grey, and uniform throughout; it is free from veins, fibres, and spots; a steel point makes an impression on it with difficulty; and the splinters broken off from it by the hammer display a conchoidal fracture.

The Munich stones are retailed on the spot in slabs or layers of equal thickness; they are quarried with the aid of a saw, so as to sacrifice as little as possible of the irregular edges of the rectangular tables or plates. One of the broad faces is then dressed, and coarsely smoothed. The thickness of these stones is nearly proportional to their other dimensions; and varies from $1\frac{2}{3}$ inch to 3 inches.

In each lithographic establishment the stones receive their finishing, dressing, and polishing; which are performed like the grinding and polishing of mirror-plate. The work is done by hand, by rubbing circularly a moveable slab over another in a horizontal position, with fine-sifted sand and water interposed between the two. The style of *work* that the stone is intended to produce determines the kind of polish that it should get. For crayon-drawing the stone should be merely grained more or less *fine* according to the fancy of the draughtsman. The higher the finish of the surface the softer are the drawings; but the printing process becomes sooner *pasty*, and a smaller number of impressions can be taken. *Works in ink* require the stone to be more softened down, and finally polished with pumice and a little water. The stones thus prepared are packed for use with white paper interposed between their faces.

Zinc plates are sometimes used in lieu of stones; they are prepared by graining the surface with fine sand, rubbed over by means of a small piece of the metal. Zinc takes a finer surface than stone, and yields more delicate impressions; but great care is necessary in keeping it dry, so that it does not corrode; this is almost the only objection to its more general use, for it is far more convenient to handle and move about than heavy stones.

Lithographic Crayons.—Fine lithographic prints cannot be obtained unless the crayons possess every requisite quality. The ingredients composing them ought to be of such a nature as to adhere strongly to the stone, both after the drawing has undergone the preparation of the acid, and during the press-work. They should be hard enough to admit of a fine point, and trace delicate lines without risk of breaking. The following composition has been successfully employed for crayons by MM. Bernard and Delarue, at Paris:—

	Parts
Pure wax (first quality)	4
Dry white tallow soap	2
White tallow	2
Gum lac	2
Lamp-black, enough to give a dark tint	1
Occasionally copal varish	1

The wax should be melted over a gentle fire, and the lac, broken to bits, is then added by degrees, stirring all the while with a spatula: the soap is next introduced in fine shavings; and when the mixture of these substances is very intimately accomplished, the copal varnish, incorporated with the lamp-black, is poured in. The heat and agitation are continued until the paste has acquired a suitable consistence; which may be recognised by taking out a little of it, letting it cool on a plate, and trying its quality with a penknife. This composition, on being cut, should afford brittle slices. The boiling may be quickened by setting the rising vapours on fire, which increases the temperature, and renders the exhalations less offensive. When ready it is to be poured into a brass mould, made of two semi-cylinders joined together by clasps or rings, forming between them a cylindric tube of the crayon size. The mould should be previously rubbed with a greasy cloth.

The soap and tallow are to be put into a small goblet and covered up. When the whole is thoroughly fused by heat, and no clots remain, the black is gradually sprinkled in with careful stirring.

Lithographic ink is prepared nearly on the same principle:—

	Parts
Wax	16
Tallow	6
Hard tallow soap	6
Shell-lac	12
Mastic in tears	8
Venice turpentine	1
Lamp-black	4

The mastic and lac, previously ground together, are to be carefully heated in the turpentine; the wax and tallow must be added after they are taken off the fire, and when their solution is effected, the soap-shavings are to be thrown in. Lastly, the lamp-black is to be well intermixed. Whenever the union is accomplished by heat, the operation is finished; the liquor is left to cool a little, then poured out on tables, and, when cold, cut into square rods.

Lithographic ink of good quality ought to be susceptible of forming an emulsion so attenuated that it may appear to be dissolved when rubbed upon a hard body in distilled or river water. It should flow in the pen, but not spread on the stone; capable of forming delicate traces, and very black, to show its delineations. The most essential quality of the ink is to sink well into the stone, so as to reproduce the most delicate outlines of the drawing, and to afford numerous impressions. It must, therefore, be able to resist the acid with which the stone is moistened in the preparation, without letting any of its greasy matter escape.

M. de Lasteyrie states that, after having tried a great many combinations, he gives the preference to the following:—

	Parts
Tallow soap, dried	30
Mastic in tears	30
White soda of commerce	30
Shell-lac	150
Lamp-black	12

The soap is first put into the goblet, and melted over the fire; the lac being added, it fuses immediately; the soda is then introduced, and next the mastic, stirring all the while with a spatula. A brisk fire is applied till all these materials are melted completely, when the whole is poured out into the mould.

The inks now prescribed may be employed, either with the pen and the hair-pencil, for writings, black-lead drawings, *aqua tinta*, mixed drawings, those which represent engraving on wood (woodcuts), &c. When the ink is to be used it is to be rubbed down with water, in the manner of China ink, till the shade be of the requisite depth. The temperature of the place ought to be from 84° to 90° Fahr., or the saucer in which the ink-stick is rubbed should be set in a heated plate. No more ink should be dissolved than is to be used at the time, for it rarely keeps in the liquid state for 24 hours; and it should be covered or corked up.

Autographic Paper.—Autography, or the operation by which a writing or a drawing is transferred from paper to stone, presents not merely a means of abridging labour, but also that of *re*verting the writings or drawings into the direction in which they were traced, whilst, if executed directly upon the stone, the impression given by it is *in*verted. Hence, a writing upon stone must be inverted from right to left to obtain direct impressions. But the art of writing thus is tedious and difficult to acquire; while, by means of the autographic paper and the transfer, proofs are obtained in the same direction with the writing and drawing.

Autographic Ink.—It must be fatter and softer than that applied directly to the stone, so that, though dry upon the paper, it may still preserve sufficient viscidity to adhere to the stone by mere pressure.

To compose this ink we take—

	Parts
White soap	100
White wax, of the best quality	100
Mutton-suet	30
Shell-lac	50
Mastic	50
Lamp-black	30 or 35

These materials are to be melted as above described for the lithographic ink.

Lithographic Ink and Paper.—The following recipes have been much commended:—

Virgin or white wax	8 parts
White soap	2 „
Shell-lac	2 „
Lamp-black	3 table-spoonfuls.

Preparation.—The wax and soap are to be melted together, and before they become so hot as to take fire, the lamp-black is to be well stirred in with a spatula, and then the mixture should be allowed to burn for 30 seconds; the flame being extinguished, the lac is added by degrees, carefully stirring all the time; the vessel is to be put upon the fire once more in order to complete the combination, and till the materials are either kindled or nearly so. After the flame is extinguished, the ink must be suffered to cool a little, and then put into the moulds.

With the ink-crayons thus made, lines may be drawn as fine as with the point of the graver, and as full as can be desired, without risk of its spreading in the carriage. Its traces will remain unchanged on paper for years before being transferred.

Some may think it strange that there is no suet in the above composition, but it has been found that ink containing it is only good when used soon after it is made, and when immediately transferred to the stone, while traces drawn on paper with the suet ink become defective after 4 or 5 days.

Lithographic Paper.—Lay on the paper 3 successive coats of sheep's-foot jelly, 1 layer of white starch, 1 layer of gamboge.

The first layer is applied with a sponge dipped in the solution of the hot jelly, very equally over the whole surface, but thin; and if the leaf be stretched upon a cord, the gelatine will be more uniform. The next two coats are to be laid on until each is dry. The layer of starch is then to be applied with a sponge, and it will also be very thin and equal. The coat of gamboge is lastly to be applied in the same way. When the paper is dry it must be smoothed by passing it through the lithographic press; and the more polished it is, the better does it take on the ink in fine lines.

Transfer.—When the paper is moistened, the transfer of the ink from the gamboge is perfect and infallible. The starch separates from the gelatine, and if, after taking the paper off the stone, we place it on a white slab of stone, and pour hot water over it, it will resume its primitive state.

The coat of gamboge ought to be laid on the same day it is dissolved, as by keeping it becomes of an oily nature; in this state it does not obstruct the transfer, but it gives a gloss to the paper which renders the drawing or tracing more difficult, especially to persons little accustomed to lithography.

The starch paste can be employed only when cold, the day after it is made, and after having the skin removed from its surface.

A leaf of such lithographic paper may be made in two minutes.

In transferring a writing, an ink drawing, or a lithographic crayon, even the impression of a copper-plate, to the stone, it is necessary, (1) that the impressions be made upon a thin and slender body, like common paper; (2) that they may be detached and fixed totally on the stone by means of pressure; but as the ink of a drawing sinks to a certain depth in paper, and adheres rather strongly, it would be difficult to detach all its parts, were there not previously put between the paper and the traces a body capable of being separated from the paper, and of losing its adhesion to it by means of the water with which it is damped. In order to produce this effect, the paper gets a certain preparation, which consists in coating it over with a kind of paste ready to receive every delineation without suffering it to penetrate into the paper. There are different modes of communicating this property to paper.

Besides the above, the following may be tried. Take an unsized paper, rather strong, and cover it with a varnish composed of—Starch, 120 parts; gum arabic, 40 parts; alum, 20 parts.

A paste of moderate consistence must be made with the starch and some water, with the aid of heat, into which the gum and alum are to be thrown, each previously dissolved in separate vessels. When the whole is well mixed, it is to be applied, still hot, on the leaves of paper, with a flat smooth brush. A tint of yellow colour may be given to the varnish with a decoction of the berries of Avignon, commonly called French berries by our dyers. The paper is to be dried, and smoothed by passing under the scraper of the lithographic press. . . . .

Steel pens are employed for writing and drawing with ink on the lithographic stones; in many establishments a sable brush is more frequently used.

Engraving on stone, for maps, geometrical drawings of every kind, patent inventions, machinery, &c., is performed with a diamond point as clearly and distinctly as if executed on copper or steel plates; to print these engraved stones, the ink should be laid on with a dabber, not a roller. Another method is by preparing the surface of the stone with a thin covering, or etching ground, of gum and black, upon which the design is traced or engraved with an etching point; it then appears in *white* lines upon a black surface. In this state the stone is taken to the printer, who applies ink to the engraved part, and washing off the gum, the drawing appears in *black* lines upon the white surface of the stone, and after being submitted to the process of fixing, described below, is ready for printing.

Lithotint, a process of drawing upon stone was adopted, first, by Mr. J. D. Harding, a few years back, and since by one or two other artists; several works were at the time executed by this method, which consists in *painting* the subject with a camel's-hair pencil, dipped in a preparation of liquid lithographic chalk, using the latter as if it were an ordinary colour, or Indian ink, sepia, &c. The results of this process were, however, so uncertain in printing, that it has been almost, if not entirely, abandoned.

The process of printing a subject executed in lithography is as follows:—The drawing is first executed by the artist on the stone in as perfect and finished a manner as if done on paper or cardboard: the stone is then washed over with nitric acid, diluted with gum, which neutralises the alkali, or soap, contained in the chalk, fixes the drawing, and cleanses the stone at the same time: this is technically called *etching*. The acid is then washed off with cold water, and any particles of the crayon or other substances which may have adhered to the surface are removed by the application of a sponge dipped in spirits of turpentine: the stone is now ready for printing: it is slightly wetted, charged with printing-ink by means of a roller, the sheet of paper, which is to receive the impression, is laid on it in a damp state, and the whole is passed through the press.

Chromolithography, or printing in colours from stones (χρῶμα, colour), is a comparatively recent introduction; but has been brought to such perfection, that works of art of the highest pictorial excellence are sometimes so closely imitated, as to deceive very competent judges. A portrait of Shakspeare, for example, executed in chromolithography by Mr. Vincent Brooks, of London, from an old oil painting, is so marvellous a copy of the original as almost to defy detection. Chromolithography, as a beautiful medium of illustration, is now in very general use: the process may be thus described, A drawing of the subject, in outline, on transfer tracing-paper, is made in the ordinary way: when transferred to a stone, this drawing is called the *keystone*, and it serves as a guide to all the others, for it must be transferred to as many different stones as there are colours in the subject; as many as thirty stones have been used in the production of one coloured print. The first stone required, generally for flat, local tints, is covered with lithographic ink where the parts should be of solid colour: the different gradations are produced by rubbing the stone with *rubbing-stuff*, or tint-ink, made of soap, shell-lac, &c. &c., and with a painted lithographic chalk where necessary; the stone is then washed over with nitric acid, and goes through the entire process described above. A roller charged with lithographic printing-ink is then passed over it to ascertain if the drawing comes as desired; and the ink is immediately afterwards washed off with turpentine: if satisfactory, this stone is ready for printing, and is worked off in the requisite colour; the next stone undergoes the same process for another colour, and so with the rest, till the work is complete: it will of course, be understood, that before any single impression is finished, it will have to pass through as many separate printings as there are drawings on stones. The colours used in printing are ground up with burnt linseed-oil, termed *varnish.*

LITHOMARGE. An iron ochre; essentially a silicate of alumina, with 6 to 7 per cent. of oxide of iron, in many respects resembling China clay or kaolin. It is found abundantly in co. Antrim. See IRON.

LITMUS (*Tournesol*, Fr.; *Lackmus*, Ger.) is prepared in Holland from the species of lichen called *Lecanora tartarea*, and *Roccella tinctoria*. The ground lichens are first treated with urine containing a little potash, and allowed to ferment for several weeks, whereby they produce a purple-red; the coloured liquor, treated with quick-lime and some more urine, is set again to ferment during two or three weeks, then it is mixed with chalk or gypsum into a paste, which is formed into small cubical pieces by being pressed into brass moulds, and dried in the shade. Litmus has a violet-blue colour, is easy to pulverise, is partially soluble in water and dilute alcohol, leaving a residuum consisting of carbonate of lime, of clay, silica, gypsum, and oxide of iron combined with the dye. The colour of litmus is not altered by alkalis, but is reddened by acids; and is therefore used in chemistry as a delicate test of acidity, either in the state of solution or of unsized paper stained with it.

Litmus is used in Holland to give a peculiar tint to certain kinds of Dutch cheese.

The preparation of litmus has been described by Ferber, Moreloz, and others.

Litmus is imported from Holland, in the form of small, rectangular, light, and friable cakes of an indigo blue colour. Examined by the microscope, we find sporules and portions of the epidermis and mesothallus of some species of lichen, moss, leaves, sand, &c. The odour of the cakes is that of indigo and violets. The violet odour is acquired while the mixture is undergoing fermentation, and is common to all the tinctorial lichens. It has led some writers into the error of supposing that the litmus-makers use Florentine orris in the manufacture of litmus. The indigo colour depends on the presence of indigo in the litmus cakes. See LICHEN.

LITMUS-PAPER. Paper coloured with an infusion of litmus, used as a test for the presence of acids.

Faraday, in his 'Chemical Manipulation,' recommended an infusion of one ounce of litmus, and half a pint of hot water. Bibulous paper is saturated with this. Prof. Graham preferred good letter-paper to the unsized paper. In order to obtain very delicate test-paper, the alkali in the litmus must be *almost* neutralised by a minute portion of acid.

LITTORAL, *a geological term.* Belonging to the sea-shore.

LIVI-DIBI. Another name for Divi-divi. See LEATHER.

LIXIVIATION (*Lessivage*, Fr.; *Auslaugen*, Ger.) signifies the abstraction by water of the soluble alkaline or saline matters present in any earthy admixture; as from that of quicklime and potashes to make potash-lye, from that of effloresced alum schist to make aluminous liquors, &c.

LLAMA. A genus of animals belonging to the class *Mammalia*, order *Ungulata*, family *Bovidæ*, and tribe *Camelina*. They are the camels of South America, to which country they are confined. In the wild state the llamas keep together in herds of from one to two hundred. There are two distinct species found wild in South America, inhabiting the Peruvian Alps, the Pampas, and the mountains of Chili. These animals are used as beasts of burthen; cords and sacks, as well as stuffs for ponchos, &c., are fabricated from their wool; and their bones are converted into instruments for weaving the same. The Alpaca, which is a variety of the llama, has given its name to a cloth manufactured from its hair; and this has become so valuable, that attempts have been made to naturalise the animal in Europe. The success, however, which has attended these attempts has not been great. The following note from the 'Penny Cyclopædia,' article 'Llāma,' is important:—

'In reference to the wool, we may here state that a herd of thirty-six, including the kinds called llamas, alpacas, and vicunas or vigonias, were sent from Lima (Peru) and Concepcion (Chili) to Buenos Ayres by journeys of two or three leagues. To those who may be inclined to import these animals, it may be necessary to state that they were fed during the journey with potatoes, maize, and hay. As soon, however, as the potatoes were exhausted, constipation came on so obstinately, that medical relief was required. They were shipped as a present from Godoy, the Prince of Peace, to the Empress Josephine, but only eleven arrived at Cadiz in 1808, just as Godoy fell into disgrace. Here two died, and the rest were near being thrown into the sea by the infuriated rabble, in their detestation of the late minister and minion. The poor llamas were however saved from the tender mercies of the populace by the governor of Cadiz, and were consigned to Don Francisco de Theran of Andalusia, who had a fine menagerie at San Lucar de Barrameda. When the French occupied the province, Marshal Soult protected them; and M. Bury St. Vincent, who was with the army, studied their habits, and executed drawings of them, which were lost at the battle of Vittoria. M. Bury paid great attention to their wool, and some from each kind was sent to the Academy of Sciences at Paris. From the report of the French naturalist and the philosophical Spaniard, it would appear that the fleece of the alpa-vigonia (produced by a cross between a vigonia and an alpaca) has much greater length than any other variety, and is six times heavier.'

The following is from James's 'History of the Worsted Manufacture in England,' p. 652:—

To commence with the earliest mention of the alpacá, we must recur to so early a period as the year 1525, when Pizarro and his ferocious companions invaded Peru. It is related by the Spanish historians, that they found there four varieties of sheep: two, the guanaco and the vicuna, in a wild state, ranging the mountainous tracts of South America; and the others, the llama, and the pacos, or alpaca, domesticated. The former of these domestic animals, partaking somewhat of the nature and size of the Arabian camel, was in like manner employed as a beast of burthen. Though in many features similar to the llama, the alpaca had several clear marks of distinction, and among others was less, and the fleece much longer and softer in fibre. In the sixteenth century, and even from the remotest times, the Peruvians being comparatively (to the other tribes of the great continent of America) a civilised people, and well acquainted with the arts of spinning and weaving, fabricated from alpaca-wool textures of much delicacy and beauty, which were highly prized as articles of dress. And that the use of them had prevailed for centuries is demonstrated by the opening of several very ancient tombs of the Peruvians, in which the dead had been enwrapped in stuffs made from the fleece of the alpaca.

In general, the alpaca ranges about four feet in height, the size of a full-grown deer, and, like it, is of graceful appearance. Its fleece is superior to the sheep in length and softness, averaging six inches (the length of the staple of the alpaca fleece is on an average much less than formerly, probably from being shorn oftener), and sometimes it has been procured even of an extraordinary length; a specimen shown at the Great Exhibition, by Messrs. Walter Milligan and Son, reaching to forty-two inches in length. The fleeces, when annually shorn, range from five to six pounds. Contrary to experience in other descriptions of wool, the fibre of the alpaca fleece acquires strength without coarseness; besides, each filament appears straight, well-formed, and free from crispness, and the quality is more uniform throughout the fleece. There is also a transparency, a glittering brightness upon the surface, giving it the glossiness of silk, which is enhanced on its passing through the dye-vat. It is also distinguished by softness and elasticity, essential properties in the manufacture of fine goods, being exempt from spiral, curly, and shaggy defects; and it spins, when treated properly according to the present improved method, easily, and yields an even, strong, and true thread. With all these remarkable qualities, it was long before the value of alpaca wool was known or appreciated in this country.

Recurring to the application of the alpaca fleece to manufacturing purposes in England, it was long delayed, though so early as the year 1807, the British troops returning from the attack of Buenos Ayres brought with them a few bags of this wool, which were submitted for inspection in London; but, observes Walton, in his work on alpaca, 'owing to the difficulty of spinning it, or the prejudice of our manufacturers, it did not then come into notice,' and for more than twenty years the attempt does not seem to have been renewed; thus depriving, for that period, the country of the advantage derived from this notable manufacture.

According to the best authorities, the first person in England who introduced a marketable fabric made from this material was Mr. Benjamin Outram, a scientific manufacturer of Greetland, near Halifax, who, about the year 1830, surmounted, with much difficulty, the obstacles encountered in spinning the wool, and eventually produced an article which sold at high prices for ladies' carriage-shawls and cloakings; but their value arose more from being rare and curious articles than from intrinsic worth.

These were, it is well established, quite destitute of the peculiar gloss and beauty which distinguish the alpaca lustres and fabrics of later times, and after a short period the manufacture was abandoned.

About the same time as Mr. Outram was weaving goods from alpaca, the wool attracted the notice of the Bradford spinners. Messrs. Wood and Walker spun it to some extent for camlet warps used in the Norwich trade. Owing to the cheapness of alpaca wool during the first years of its consumption in England, it was occasionally employed instead of English hog wool for preparing lasting and camblet warps, being spun to about No. 48.

The earliest manufacture of the alpaca-wool into goods at Bradford appears to have occurred under these circumstances. In the commencement of 1832 some gentlemen, connected with the trade to the west coast of South America, were on a visit at the house of J. Garnett, Esq., of Clithero, and, on their alluding to the difficulty of meeting with suitable returns for goods forwarded to that part of the world, he suggested to them the transmission of alpaca-wool, and offered, if they would send him a few pounds weight to ascertain its value for manufacturing purposes. In a few months he received some samples of alpaca-wool, which, on October 2, 1832, he forwarded to Messrs. Horsfall of Bradford, with a request that they would test its value. Accordingly, they fabricated from this wool a piece resembling heavy camblet, which they showed to the Leeds merchants; but the piece, not developing any peculiar qualities of alpaca, did not please, so that Messrs. Horsfall were not encouraged to proceed further with experiments. However, in the same year Messrs. Hoyam, Hall, and Co., spirited merchants of Liverpool, perceiving the value of the alpaca-wool, directed their agents in Peru to purchase and ship over all the parcels of alpaca-wool they could meet with; some of which, being sent to the Bradford district, was spun and manufactured by several parties there. The pieces chiefly fabricated from alpaca in the neighbourhood of Bradford were figures made with worsted warp and alpaca weft, the figures being raised and lustrous, like union damasks. These goods were in vogue only for a limited time, for neither the figured nor plain ones seem to have suited the public taste.

Until the introduction of cotton warps into the worsted trade it may safely be averred that the alpaca manufacture had not been developed, and would never have made much progress without being combined with cotton or silk warp. To Sir Titus Salt, of Bradford, must undoubtedly be awarded the high praise of finally overcoming the difficulties of preparing and spinning the alpaca-wool so as to produce an even and true thread; and, by combining it with cotton warps, which had then (1836) been imported into the trade at Bradford, improved the manufacture so as to make it one of the staple industries of the kingdom. He has, by an admirable adaptation of machinery, been enabled to work up the material with the ease of ordinary wool, and thus present beautiful alpaca-stuffs at a reasonable rate. Every previous attempt had been made, as far as can be ascertained, with worsted warps, with which the alpaca did not easily assort.

About the year 1836 the alpaca trade had become established, and has since risen to much importance. After this period the manufacture rapidly extended. The great mercantile house of A. and S. Henry took very large quantities of alpaca-stuffs, which began to be made in an endless variety of goods suited both for male and female dress, including scarfs, handkerchiefs, and cravats, plain and figured goods, both with silk and cotton warp, for ladies' dresses, dyed alpaca checks of beautiful texture, and a variety of grograms, codringtons, silk-striped, checked, and figured alpacas and alpaca linings. The demand for these various alpaca fabrics during the period between 1841 and 1846 remained uniform and steady.

At the commencement of the manufacture of alpaca goods with cotton warps (silk was not used) the weft was spun from fine qualities of the wool into low numbers, and the pieces were made much richer and heavier than has been the case more recently, the demand having altered in favour of lighter and less costly cloth.

Most of the alpaca-wool brought into the United Kingdom is unshipped at Liverpool, but a small portion is also carried to London. At these two ports, it may be asserted, the whole imported into this country is landed. It arrives in small bales, called ballots, weighing about 70 lbs., and is generally in an impure state, with different qualities mixed. Like the fleece of the sheep, that of the alpaca is composed of different qualities, so that the portion growing on the hind-quarters is of an inferior description. The wool is sorted into about eight different qualities, each fitted for a particular class of goods. Owing to the dirty state of the fleeces, and the peculiar nature of the dusty particles arising during the progress of sorting, the operation is an unhealthy one, unless great care be taken by ventilation to counteract this baneful effect. After being sorted, it is at Saltaire washed and combed by machinery. Until of late years it was combed wholly by hand, and the combs used for this purpose were of a deeper pitch than those usually adopted for preparing sheep's wool, that is, those combs had a larger number of teeth than ordinary. The next process is to draw the sliver, which is perfected by an improved gill-machine, especially adapted for this material. And here, in combing and preparing the alpaca-wool, so as to make a clean, even, and glossy thread, lay the grand difficulty in the way of applying the alpaca-fibre to the worsted manufacture, and which was so successfully surmounted by Sir Titus Salt.

The main articles now manufactured from alpaca-wool consists of alpaca lustres, which are dyed, and alpaca mixtures, which are undyed; and both are made of cotton or silk warp. These plain goods may, from their extensive and steady use, be termed stock-articles. Large quantities of fancy alpacas are made, but they are rapidly varying, and are distinguished by innumerable names. The material is at present much shorter in staple than formerly, owing to the alpaca being shorn oftener, so that it is now commonly from 5 to 8 inches in length. Nearly all the alpaca-wool consumed in England is worked up in the Bradford district.

Dating from the year 1834, when the importation of alpaca-wool sprung up as a permanent branch of commerce, the demand in this country has, on the whole, been a growing one. Mr. Walton, in his work on the alpaca, exhibits the quantities imported until the year 1843, when, the tariff law having come into operation, the returns began to be more correctly framed, and the alpaca-wool was then classed by itself.

Our imports were in 1843, 1,458,032 lbs.; in 1853, 2,148,267 lbs. These large quantities were yet increased in 1863, when we imported from Peru, 2,772,836 lbs.; from New Granada, 622,889 lbs.; and 6,857 lbs. from other parts; and the *Imports* of llama, alpaca, and vicuna during the three years ending 1872 were as follows:—

	1870		1871		1872	
	lbs.	Value	lbs.	Value	lbs.	Value
From Germany . .	..	..	..	..	184,144	£34,450
,, Peru . . .	3,324,454	£388,969	3,083,328	£402,590	3,522,314	460,532
,, Chili . . .	563,782	65,996	565,855	80,861	124,219	20,417
,, Other countries .	800	14	2,067	282	48,062	6,433
Total . .	3,888,536	454,979	3,651,250	483,733	3,878,739	521,839

In the interval, the price had, with the demand, progressively increased: the price in 1834 only amounted to about 8½*d.* per pound; next year it reached nearly 10*d.*; the year after, 1*s.*; in 1838, to upwards of 1*s.* 3½*d.*; and in 1839 to 1*s.* 4*d.*

During the last ten years the prices have fluctuated considerably. In 1844, 1*s.* 8*d.* per pound was quoted as the price of the white fleece, and 2*s.* for the black one. In the year 1855, according to the price-currents, the average rates were thus quoted:—

	s.	*d.*		*s.*	*d.*
Alpaca, best white	2	6	to	2	8
,, brown and black	2	6	,,	2	8
Vicuna, best dark coloured	3	0	,,	3	6
Llama	0	10½	,,	1	3

But these quotations are somewhat higher for alpaca-wool than the prices now realised, which of late years have ranged from 2*s.* to 2*s.* 2*d.* per pound.

Alpaca Fat was shown in the Exhibition of 1862, and was stated to be remarkable in its power of resisting rancidity. It was thought this would make it valuable to the arts, especially in perfumery.

LOAD. A burthen or freight. As the various quantities of material contained in a load cannot but be useful, the following Table is borrowed from Mr. P. L. Simmonds's 'Trade Products,' &c.:—

Corn . .	5 qrs. or 40 bushels.	Bricks . .	500.
Straw . .	36 trusses, or 11 cwts. 64 lbs.	Tiles . .	1,000.
Old hay .	18 cwts.	Lead ore (in Derbyshire)	9 dishes or nearly 3 cwts.
New hay .	19 cwts. 32 lbs.	Bulrushes .	63 bundles.

Mortar	27 feet.	Timber:—	square feet
Coffee, in bags	12 cwts.	2 inch plank	300
Rice	10 „	2½ „	240
Timber:—	square feet	3 „	200
1 inch plank	600	3½ „	170
1½ „	400	4 „	150

LOADSTONE, *Magnetic Iron-stone.* (*Fer oxydulé,* Fr.; *Magneteisenstein,* Ger.) An iron ore, consisting of the protoxide and peroxide of iron in a state of combination.

It was first discovered in Magnesia, and from that province has been derived the name MAGNET applied to this ore of iron. The term loadstone, however, is given to those specimens which are powerfully magnetic only. See IRON.

LOAM. (*Terre limoneuse,* Fr.; *Lehm,* Ger.) A native clay, mixed with quartz-sand and iron-ochre, and occasionally with some carbonate of lime.

'More commonly we find sand and clay, or clay and marl, intermixed in the same mass. When the sand and clay are each in considerable quantities, the mixture is called "loam."'—*Lyell.*

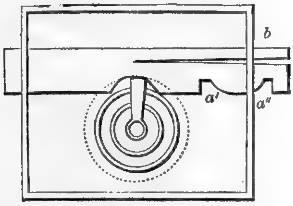
LOCKS. Although locks are distinctly a manufacture, yet they were not embraced in the early editions of this work; the chief cause of this being the desire on the part of Dr. Ure to limit the articles of the Dictionary to such manufactures as were not comprehended within his meaning of the term Handicraft.

The lock manufacture is essentially one of handicraft; and seeing that these volumes could not possibly enter into any detailed description of this and numerous other trades, as watch-making and the like, it has been determined that a brief notice of the several kinds of locks alone shall find a place in its pages.

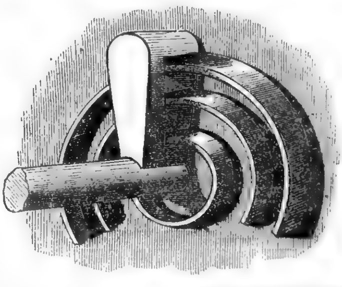
The lock manufacture of this country is confined almost exclusively to Wolverhampton and the neighbouring village of Willenhall. There are very few large manufactories, almost all kinds of locks being made by small masters, employing from half-a-dozen to a dozen men.

In nearly every kind of lock a bolt shoots out from the box or lock, usually of an oblong shape, and catches in some kind of staple or box fixed to receive it. In some a staple enters the lock, and the bolt passes through the staple within the lock. The lock of a room-door is of the first character; the lock of a writing-desk, or ordinary box, is of the second kind. The key is merely a bent piece of iron, which, on entering the lock, can move freely, and push forward the bolt. To the bolts of superior locks springs are attached, and the force required to turn the key in a lock is the force necessary to overcome the resistance of the springs. The following two figures, 1397, 1398, represent the character of a lock with wards or wheels, which are introduced to give safety. *Fig.* 1397 is an ordinary back-spring lock, representing the bolt half-shot; *a′ a″* are notches on the under side of the bolt, connected by a curved portion; *b* is the back-spring, which is of course compressed as the curved portion of the bolt passes through the aperture prepared for it in the rim of the lock; when the bolt is withdrawn, the notch *a′* rests in the rim; when the bolt is shot, the notch *a″* rests in the same manner. The action of the key and wards is shown in *fig.* 1398. The curved pieces of metal are the wards; and there are two clefts in the bit of the key to enable it to move without interruption.

1397

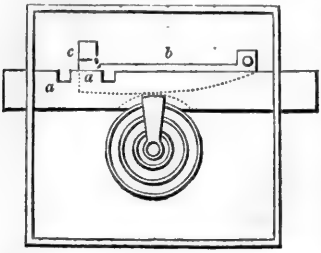


1398



The tumbler-lock is shown in its most simple form in *fig.* 1399. Here the bolt has two slots, *a a*, in the upper part; and behind the bolt is a kind of latch, *b*, which carries a projecting piece of metal; *c*, this is the tumbler, which moves freely on a pivot at the other end. When the bolt is fully shot the projecting piece of metal falls into one notch, and when withdrawn it falls into the other. It will be evident here that the action of the key is to raise the tumbler, so that the bolt has free motion: this action will be intelligible by tracing the action of the key on the dotted lines. These tumbler-locks are greatly varied in character; but in principle they are as above described.

1399



Numerous well-known locks have been patented, the most remarkable being Chubb's lock, which has been fully described by the inventors in a paper read before the Institution of Civil Engineers; and also in an excellent treatise on locks to be found in Mr. Weale's series of useful manuals. This lock is essentially a tumbler-lock, it being fitted up with no less than six tumblers; and the key has to raise, by a series of steps, these before the bolt is free to move. It will be obvious, that unless the key is exactly fitted to move these, there is no chance of moving the bolt. In this paper already alluded to Mr. Chubb says:—

'The number of changes which may be effected on the keys of a three-inch drawer-lock is 1 × 2 × 3 × 4 × 5 × 6 = 720, the number of different combinations which may be made on the six steps of unequal lengths without altering the length of either step. The height of the shortest step is however capable of being reduced, 20 times; and each time of being reduced, the 720 combinations may be repeated; therefore 720 × 20 = 14,400 changes.' By effecting changes of this character, therefore, almost any number of combinations can be produced. The Bramah lock has been long celebrated, and most deservedly so. Notwithstanding the fact that this lock was picked by Mr. Hobbs after having the lock in his possession for sixteen days, it appears to us that it most fully justifies the boast made by Mr. Bramah in his 'Dissertation on the Construction of Locks.' 'Being confident,' he says, 'that I have contrived a security which no instrument but its proper key can reach, and which may be so applied as not only to defy the art and ingenuity of the most skilful workman, but to render the utmost force ineffectual, and thereby to secure what is most valued as well from dishonest servants as from the midnight ruffian, I think myself at liberty to declare (what nothing but the discovery of an infallible remedy would justify my disclosing) that all dependence on the inviolable security of locks, even of those which are constructed on the best principle of any in general use, is fallacious.' He then proceeds to demonstrate the imperfections of ordinary locks, and to describe his own.

'The body of a Bramah lock may be considered as formed of two concentric brass barrels, the outer one fixed, and the inner rotating within it. The inner barrel has a projecting stud, which, while the barrel is rotating, comes in contact with the bolt in such a way as to shoot or lock it; and thus the stud serves the same purpose as the bit of an ordinary key, rendering the construction of a bit to the Bramah key unnecessary. If the barrel can be made to rotate to the right or left, the bolt can be locked or unlocked, and the problem is, therefore, how to insure the rotation of the barrel. The key, which has a pipe or hollow shaft, is inserted in the keyhole upon the pin, and is then turned round; but there must be a nice adjustment of the mechanism of the barrel before this turning round of the key and the barrel can be insured. The barrel has an external groove at right angles to the axis, penetrating to a certain depth; and it has also several internal longitudinal grooves from end to end. In these internal grooves thin pieces of steel are able to slide, in a direction parallel with the axis of the barrel. A thin plate of steel, called the locking plate, is screwed in two portions to the outer barrel, concentric with the inner barrel; and at the same time occupying the external circular groove of the inner barrel; this plate has notches, fitted in number and size to receive the edges of the slides which work in the internal longitudinal grooves of the barrel. If this were all, the barrel could not revolve, because the slides are catching in the grooves of the locking plate; but each slide has also a groove, corresponding in depth to the extent of this entanglement; and if this groove be brought to the plane of the locking plate, the barrel can be turned, so far as respects the individual slide. All the slides must, however, be so adjusted, that their grooves shall come to the same plane; but, as the notch is cut at different points in the lengths of the several slides, the slides have to be pushed in to different distances in the barrel, in order that this juxtaposition of notches may be insured. This is effected by the key, which has notches or clefts at the end of the pipe equal in number to the slides, and made to fit the ends of the slides when the key is inserted; the key presses each slide, and pushes it so far as the depth of its cleft will permit; and all these depths are such that all the slides are pushed to the exact position where their notches all lie in the same plane; this is the plane of the locking plate, and the barrel can be then turned.'—*Tomlinson on the Construction of Locks.* In this work the details of construction are given with great clearness.

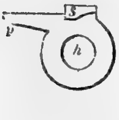
The American bank locks, especially that of Messrs. Day and Newall, have excited much attention. Their English patent describes it thus:—

'The object of the present improvements is the constructing of locks in such manner that the interior arrangements, or the combination of the internal moveable parts, may be changed at pleasure according to the form given to, or change made in, the key, without the necessity of arranging the moveable parts of the lock by hand, or removing the lock or any part thereof from the door. In locks constructed on this plan the key may be altered at pleasure; and the act of locking, or throwing out the bolt of the lock, produces the particular arrangements of the internal parts, which correspond to that of the key for the time being. While the same is locked, this form is retained until the lock is unlocked or the bolt withdrawn, upon which the internal moveable parts return to their original position, with reference to each other; but these parts cannot be made to assume or be brought back to their original position, except by a key of the precise form and dimensions as the key by which they were made to assume such arrangement in the act of locking. The key is changeable at pleasure, and the lock receives a special form in the act of locking according to the key employed, and retains that form until in the act of unlocking by the same key it resumes its original or unlocked state. The lock is again changeable at pleasure, simply by altering the arrangement of the moveable bits of the key; and the key may be changed to any one of the forms within the number of permutations of which the parts are susceptible.'—April 15, 1851.

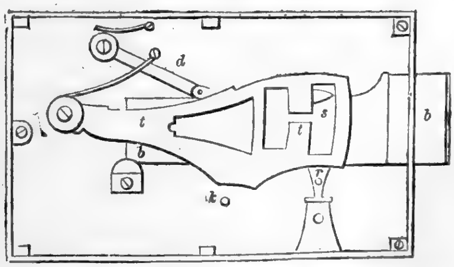
Mr. Hobbs who has been carrying out the manufacture of American locks in this country has introduced an inexpensive lock, which he calls a *protector lock.* The following description is borrowed from Mr. Charles Tomlinson's 'Treatise on the Construction of Locks':—

'When the American locks became known in England, Mr. Hobbs undertook the superintendence of their manufacture, and their introduction into the commercial world. Such a lock as that just described must necessarily be a complex piece of mechanism; it is intended for use in the doors of receptacles containing property of great value; and the aim has been to baffle all the methods at present known of picking locks, by a combination of mechanism necessarily elaborate. Such a lock must of necessity be costly; but in order to supply the demand for a small lock at moderate price, Mr. Hobbs has introduced what he calls a *protector lock.* This is a modification of the ordinary six-tumbler lock. It bears an affinity to the lock of Messrs. Day and Newall, inasmuch as it is an attempt to introduce the same principle of security against picking, while avoiding the complexity of the changeable lock. The distinction which Mr. Hobbs has made between secure and insecure locks will be understood from the following proposition: viz. 'that whenever the parts of a lock which come in contact with the key are so affected by any pressure applied to the bolt, or to that portion of the lock by which the bolt is withdrawn, as to indicate the points of resistance to the withdrawal of the bolt, such a lock can be picked.' *Fig.* 1401 exhibits the internal mechanism of this new patent lock. It contains the usual contrivances of tumblers and springs, with a key cut into steps to suit the different heights to which the tumblers must be raised. The key is shown separately in *fig.* 1402. But there is a small additional piece of mechanism, in which the *tumbler stump* shown at *s* in *figs.* 1400 and 1401 is attached; which piece is intended to work under or behind the bolt of the lock. In *fig.* 1401, *b* is the bolt; *t t* is the

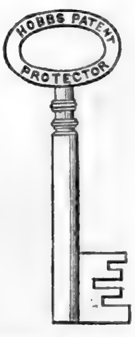
1400



1401



1402



front or foremost of the range of six tumblers, each of which has the usual slot and notches. In other tumbler-locks the stump or stud which moves along these slots is riveted to the bolt, in such manner that, if any pressure be applied in an attempt to withdraw the bolt, the stump becomes pressed against the edges of the tumblers, and bites or binds against them. How far their biting facilitates the picking of a lock will be shown further on; but it will suffice here to say, that the moveable action given to the stump in the Hobbs lock transfers the pressure to another quarter. The stump *s* is riveted to a peculiarly-shaped piece of metal *h p* (*fig.* 1400), the hole in the centre of which fits upon a centre or pin in a recess formed at the back of the bolt; the piece moves easily on its centre, but is prevented from so doing spontaneously by a small binding spring. The mode in which this small moveable piece takes part in the action of the lock is as follows: when the proper key is applied in the usual way, the tumblers are all raised to the proper heights for allowing the stump to pass horizontally through the grating; but should there be an attempt made, either by a false key or by any other instrument, to withdraw the bolt before the tumblers are properly raised, the stump becomes an obstacle. Meeting with an obstruction to its passage, the stump turns the piece to which it is attached on its centre, and moves the arm of the piece *p* so that it shall come into contact with a stud riveted into the case of the lock; and in this position there is a firm resistance against the withdrawal of the bolt. The tumblers are at the same moment released from the pressure of the stump. There is a dog or lever *d*, which catches into the top of the bolt, and thereby serves as an additional security against its being forced back. At *k* is the drill-pin on which the pipe of the key works; and *r* is a metal piece on which the tumblers rest when the key is not operating upon them.

Another lock, patented by Mr. Hobbs in 1852, has for its object the absolute closing of the key-hole during the process of locking. The key does not work or turn on its own centre, but occupies a small cell or chamber in a revolving cylinder, which is turned by a fixed handle. The bit of the moveable key is entirely separable from the shaft or stem, into which it is screwed, and may be detached by turning round a small milled headed thumb-screw. The key is placed in the key-hole in the usual way, but it cannot turn; its circular movement round the stem as an axis is prevented by the internal mechanism of the lock; it is left in the key-hole, and the stem is detached from it by unscrewing. By turning the handle, the key-bit, which is left in the chamber of the cylinder, is brought into contact with the works of the lock, so as to shoot and withdraw the bolt. This revolution may take place whether the bit of the moveable key occupy its little cell in the plate or not; only with this difference—that if the bit be *not* in the lock, the plate revolves without acting upon any of the tumblers; but if the bit be in its place, it raises the tumblers in the proper way for shooting or withdrawing the bolt. It will be understood that there is only one key-hole, namely, that through which the divisible key is inserted; the other handle or fixed key working through a hole in the cover of the lock only just large enough to receive it, and not being removable from the lock. As soon as the plate turns round so far as to enable the key-bit to act upon the tumblers, the key-hole becomes entirely closed by the plate itself, so that the actual locking is effected at the very time when all access to the interior through the key-hole is cut off. When the bolt has been shot, the plate comes round to its original position, it uncovers the key-hole, and exhibits the key-bit occupying the little cell into which it had been dropped; the stem is then to be screwed into the bit, and the latter withdrawn. It is one consequence of this arrangement, that the key has to be screwed and unscrewed when used; but through this arrangement the key-hole becomes a sealed book to one who has not the right key. Nothing can be moved, provided the bit and stem of the key be both left in; but by leaving in the lock the former without the latter, the plate can rotate, the tumblers can be lifted, and the bolt can be shot.

LOCUST TREE. A North American tree, the *Robinia pseudacacia*. 'It grows most abundantly in the southern States; but it is pretty generally diffused through the whole country. It sometimes exceeds four feet in diameter and seventy feet in height. The locust is one of the very few trees planted by the Americans.' This wood is much used for ships' tree-nails, and is employed for stakes and pales.

The wood of the *Hymenæa Courbaril* is also known as locust wood.

LODE (*a mining term*). A mineral lode, or a mineral vein, is the name given to a fissure in the crust of the earth which has been filled in with metalliferous matter. The miner gives the same name *lode* to a fissure filled with quartz, carbonate of lime, &c., but then he says the lode is not 'mineralised,' confining the word 'mineral' to metalliferous matter.

The term *vein* has frequently led to the idea that it expresses the condition of something analogous to the blood-vessels of the animal body, to which a lode has not in the remotest degree any resemblance. During some primary convulsions, the crust of the earth has been cracked, these fissures having, of course, some special relation to the direction of the force which produced them. These cracks have during ages of submergence been filled in, according to some law of polarity, with mineral matter, the character of the lode having generally some special relation to its direction. See Mining.

LOGWOOD (*Bois de Campêche, Bois bleu*, Fr.; *Blauholz*, Ger.) is the wood of the *Hæmatoxylon Campechianum*, a native tree of Central America, grown in Jamaica since 1715. It was first introduced into England in the reign of Elizabeth, but as it afforded to the unskilful dyers of her time a fugitive colour, it was not only prohibited from being used, under severe penalties, but was ordered to be burned wherever found, by a law passed in the 23rd year of her reign. The same prejudice existed, and the same law was enacted against indigo. At length, after a century of absurd prohibition, these two most valuable tinctorial matters, by which all our hats, and the greater part of our woollen cloths, are dyed, were allowed to be used. The logwood tree grows from 40 to 50 feet high, the stems are cut into logs of about 3 feet long, the bark and white sap (alburnum) of which are chipped off, the heart or red part only being sent to England. Chevreul gave the constituents of logwood as *volatile oil, hæmatin, resinous matter, tannin, glutinous matter, acetic acid*, sundry salts of *lime*, with *alumina, silica, manganese, and iron*. The decoction of logwood is of a deep dull red, which is rendered paler and of a brighter colour by acids. Alkalis give it a purplish or violet colour. Acetate of lead causes a blue, alum a violet precipitate; the salts of iron make it a dark violet blue, gelatine forming a reddish precipitate with it. The colouring principle of logwood is a crystallisable substance known as *hæmatoxylin*, which contains $C^{16}H^{7}O^{6}$ ($\mathbf{C^{16}H^{14}O^{6}}$).

Old wood, with black bark and with little of the white alburnum, is preferred. Logwood is denser than water, specific gravity, 1·057, very hard, of a fine compact grain, and almost indestructible by the atmospheric elements; it has a sweet and astringent taste, and a peculiar but inoffensive smell, and will take a fine polish.

When chipped logwood is for some time exposed to the air, it loses a portion of its dyeing power. Its decoction absorbs the oxygen of the atmosphere, and then acquires the property of precipitating with gelatine, which it had not before. The dry extract of logwood, made from an old decoction, affords only a fugitive colour.

For its applications in dyeing, see Black Dye; Calico Printing; Dyeing; Hat Dyeing, &c.

Imports of Logwood.

	1871		1872	
	Tons	£	Tons	£
From France	649	4,885	...	...
„ United States . . .	705	4,755	616	4,004
„ Spanish West Indies. .	190	2,090	...	...
„ Hayti and Domingo . .	2,832	12,791	4,319	23,864
„ Mexico	1,009	7,693	2,099	18,220
„ British West Indies . .	24,059	115,957	32,792	157,346
„ British Honduras . .	9,174	43,550	5,660	25,693
„ Other countries. . .	728	4,080	535	3,908
Total . . .	39,346	195,801	46,021	233,035

LÖLINGITE. An arsenide of iron, resembling mispickel. It is occasionally auriferous, and has been worked for gold at Reichenstein in Silesia. See Pyrites.

LOOKING GLASS. See Mirrors.

LOOM (*Métier à tisser*, Fr.; *Weberstuhl*, Ger.) is the ancient and well-known machine for weaving cloth by the decussation of a series of parallel threads, which run lengthwise, called the warp or chain, with other threads thrown transversely with the shuttle, called the woof or weft. See Jacquard Loom and Weaving.

LOVAGE. The *Levisticum officinale*, an umbelliferous plant, with aromatic fruit.

LUBRICANTS. Oleaginous or fatty bodies employed for the purpose of reducing the friction between two parts of a machine or carriage.

LUBRICATING OIL. This name has recently been specially given to an oil or grease prepared from the mineral naphthas. It ought to have a specific gravity varying from 0·920 to 0·950, and to possess but a very slight odour. Although it contain paraffin, yet it ought not to deposit any when cooled to 2° Cent. See Naphtha.

LUBRICATION. The lubrication of the wheel and axle of railway carriages is effected by a kind of soap: a combination of cocoa-nut oil or palm oil, or ordinary fats, with soda being the 'grease' with which the boxes are filled. The heat produced by the friction melts the grease, and it flows out upon the parts in motion through an opening in the bottom of the box. Heavy machinery, such as pumping-engines, require tenacious bodies as their lubricants, while the finer parts must be carefully oiled with oils as free as possible from any of the fatty acids. Spinning machinery, for example, must be lubricated with the finest oils, or, as it is found to be still better, with those peculiar hydro-carbon compounds, as paraffin, glycerine, and the like. The following is a simple and efficacious plan of lubricating the joints and bearings of machinery by capillary attraction, the invention of Edward Woolsey, Esq. :—

Fig. 1403 represents a tin cup, which has a small tin tube A, which passes through the bottom. It may have a tin cover to keep out the dust.

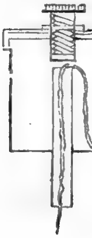
Fig. 1404 is a plan of the same.

Fig. 1405 is a section of the same. Oil is poured into the cup, the one end of a worsted or cotton thread is dipped into the oil, and the other end passed through the tube.

The capillary attraction causes the oil to ascend and pass over the orifice of the tube, whence it gradually descends, and drops slower or quicker according to the length of the thread or its thickness, until every particle of oil is drawn over by this capillary siphon. The tube is intended to be put into the bearings of shafts, &c., and is made of any size that may be wished. If oil, or other liquids, is desired to be dropped upon a grindstone or other surface, this cup can have a handle to it, or be hung from the ceiling.

Fig. 1406. It is frequently required to stop the capillary action when the machinery is not going; and this has been effected by means of a tightening screw, which passes through a screw boss in the cover of the cup, and presses against the internal orifice of the tube, preventing the oil from passing.

Fig. 1407. As when these screw cups are used upon beams of engines and moving bearings, the screw is apt to be tightened by the motion; and also, as the action of the screw is uncertain, from the workman neglecting to screw it down sufficiently, it answers best to take out the capillary thread when the lubrication is not required; and to effect this easily, a tin top is fixed to the cup, with a round pipe soldered to it; this pipe has a slit in it, like a pencil-case, and allows a bolt B to slide easily. In *fig.* 1408 the bolt is down; in *fig.* 1409 the bolt, which is a piece of brass wire, is drawn up, and thus the flowing of the oil is checked. In *fig.* 1409 it will be observed, that the bolt is kept in its place by its head C, resting in a lateral slit in the pipe, and it cannot be drawn out on account of the pin E. One end of the thread is fastened to the eye-hole at the bottom of the bolt, and the other end is tied to a small wire which crosses the lower orifice of the tube at D, and which is shown in plan, *fig.* 1410.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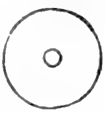
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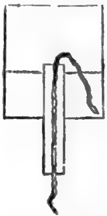
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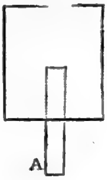

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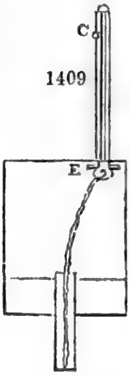

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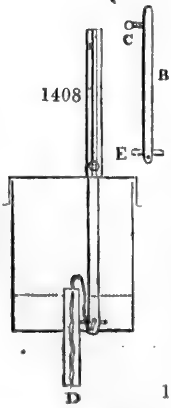

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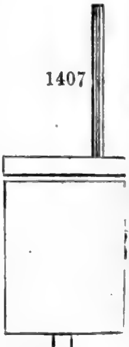

1407

1410

The saving by this plan, instead of pouring oil into the bearings, is 2 gallons out of 3, while the bearings are better oiled.

The saving in labour is considerable where there are many joints to keep oiled three or four times a day; and the workman does not, with this apparatus, run the risk of being caught by the machinery. To tie on the cotton or worsted thread, pass a long thread through the eye-hole, E, of the bolt, and then draw the two ends through the tube by a fine wire with a hook to it, one end on one side of the cross-wire D, and the other end on the other side. Then put the cover on, and the bolt in the position shown in *fig.* 1409; when, by drawing the two ends of the thread, and tying them across the wire D, you have the exact length required. When you wish to see the quantity of oil remaining in the lubricator, the bolt must be dropped, as in *fig.* 1408, and you can then lift the cover a little way off, without breaking the thread, and replenish with oil. The figures in the woodcut are one-third of the full size.

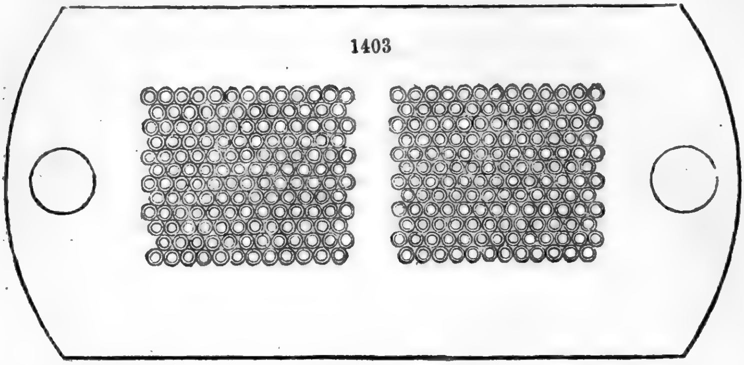
LUCIFER MATCHES. The importance of this manufacture has been shown by Mr. Tomlinson in a communication made by that gentleman to the 'Journal of the Society of Arts.' 'It has been estimated,' he says, 'that the English and French manufacturers of phosphorus are now producing at the rate of 300,000 lbs. of common phosphorus per annum, nearly the whole of which is consumed in making lucifer matches. In compounding the emulsion for tipping the matches, the German manufacturers make three pounds of phosphorus suffice for five or six millions of matches. If we suppose only one-half of the French and English annual product of phosphorus to be employed in making matches, this will give us 250,000,000,000 of matches as the annual product consequent on the consumption of one-half of the French and English phosphorus. We need not suppose this to be an exaggerated statement when we consider the daily product of some of our match manufactories. I lately had occasion to describe the processes of a London factory, which produces 2,500,000 matches daily. For this purpose, fourteen 3-inch planks are cut up; each plank produces 30 blocks; each block, of the dimensions of 11 inches long, 4½ inches wide and 3 inches thick, produces 100 slices; each slice 31 splints; each splint 2 matches: thus we have—14 × 30 × 100 × 31 × 2 = 2,604,000 matches as the day's work of a single factory in London. At Messrs. Dixon's factory, near Manchester, from 6,000,000 to 9,000,000 of matches are produced daily.'

The lucifer matches formerly employed for procuring a light were the wooden sulphur matches, coated with a paste containing phosphorus, which, when dry, would ignite by friction. To prepare the paste, phosphorus was melted with a certain quantity of water at 120°, the requisite proportion of nitrate, with a small proportion of chlorate of potash, was dissolved in this water, a small quantity of binoxide of manganese or red lead added, and the liquid thickened with gum; the whole was well triturated together in a mortar till the globules of phosphorus ceased to be visible to the eye, and the mass was coloured with Prussian blue or with minium. The points of the matches were dipped into this paste, and then cautiously dried in a stove. The use of the gum was to serve as a varnish to protect the phosphorus from oxidation by the air.

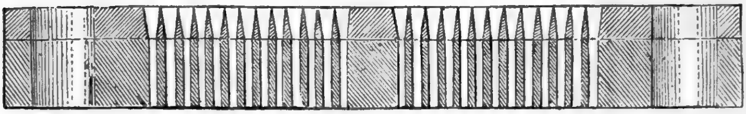
For the rapid manufacture of the wooden splints for lucifer matches, a patent was obtained by Mr. Reuben Partridge, in March 1842. He employed a perforated metallic plate, having a steel face, strengthened by a bell-metal back; see *figs.* 1411, 1412. The size of the perforations must depend on that of the desired splints; but they must be as close together as possible, that there may be a very small blank space between them, otherwise the plate would afford too great a resistance to the passage of the wood. By this construction, the whole area of the block of wood may be compressed laterally into the countersunk openings, and forced through the holes, which are slightly countersunk to favour the entrance and separation of the wooden fibres. *Fig.* 1411 represents the face of one of these plates; and *fig.* 1412 is a rectangular section through the plate. A convenient size of plate is 3 inches broad, 6 inches long, and 1 inch thick. The mode of pressing is by fixing the back of the plate against a firm resisting block or bearing, having an aperture equal to the area of the perforations in the plate, and then placing the end of the piece or pieces of wood in the direction of the grain against the face of the plate within the area of the perforated portion. A plunger or lever, or other suitable mechanical agent, being then applied to the back or reverse end of the piece of wood, it may be forced through the perforations in the plate, being first split as it advances by the cutting edges of the holes, and afterwards compressed and driven through the perforations in the plate, coming out on the opposite side or back of the plate in the form of a multitude of distinct splints, agreeably to the shapes and dimensions of the perforations.

The first stage in the manufacture of lucifers is the cutting the wood, which is done, according to the extent of the manufactory, either by hand or by machinery. This, as well as the subsequent process of counting and placing the matches in frames, is in itself necessarily free from any inconvenience or evil consequences; nor does it appear that the third stage, which consists of melting the sulphur and dipping the heads of the matches in it, produces any inconvenience. The fourth, fifth, sixth, and seventh stages comprise the grinding, mullering, and mixing of the explosive compound; the process of dipping the matches in it, the counting and boxing. The dipping, counting, and packing appear to be, according to Mr. Geist, the only departments in which the workpeople are in any way affected with peculiar complaints; we would even limit the appearance of the jaw-disease to those engaged in dipping—at least, all that we have examined on the subject were unanimous as to the fact that dippers only were attacked. There is a certain degree of secrecy observed relative to the proportions of the composition; and the mixture of the materials is generally performed by the proprietor of the manufactory, or by a confidential workman. Chlorate of potash is considered an essential ingredient in England; but in the manufactories at Nürnberg it has not been employed for a number of years, as its explosive properties much endangered the safety of the buildings and the limbs of the workmen.

1403



1404



The composition used in Nürnberg consists of one-third of phosphorus, of gum-arabic (which is eschewed by English manufacturers on account of its hygrometric property), of water, and of colouring-matter, for which either minium or Prussian blue is employed. If ignition be required without a flame, the quantity of phosphorus is diminished, or nitrate of lead is added. The mixing is conducted in a water-bath; and during this process, and as long as the phosphorus is being ground or 'mullered,' copious fumes are evolved. The dipping is performed in the following manner:—The melted composition is spread upon a board covered with cloth or leather, and the workman dips the two ends of the matches alternately that are fixed in the frame; and as this is done with great rapidity, the disengagement of fumes is very considerable, and the more liable to be injurious, as they are evolved in a very concentrated form close to the face of the workman. This department is generally left to a single workman; and the average number that he can dip in an hour, supposing each frame to hold 3,000 matches, would be 1,000,000.

As the matches have been dipped, they require to be dried. This is generally done in the room in which the former process is carried on; and as a temperature of from 80° to 90° Fahr. is necessary, the greatest quantity of fumes is evolved at this stage. When the matches are dried, the frames are removed from the drying-room, and the lucifers are now ready to be counted out into boxes. As this is done with great rapidity they frequently take fire, and, although instantly extinguished in the sawdust or the water which is at hand, the occurrence gives rise to an additional and frequent evolution of fumes.

The composition of lucifer matches varies greatly, as it regards the proportions of the materials employed. In principle they are, however, as we have described them above; everything depending on the ignition of the phosphorus, and the perfection of a lucifer match is in tipping the match with a composition which will ignite quietly upon attrition against any rough surface, but which is not liable to ignition by such pressure as it may be subjected to under the ordinary condition of keeping in closed boxes.

According to Dr. R. Böttger, in *Annalen der Chemie und Pharmacie*, vol. xlvii. p. 334, the best composition for lucifer matches is—

	Parts		Parts
Phosphorus	4	Red ochre, or red lead	5
Nitre	10	Smalt	2
Fine glue	6		

Convert the glue, with a little water, by a gentle heat into a smooth jelly, put it into a slightly-warm porcelain mortar to liquefy; rub the phosphorus down through this gelatine at a temperature of about 140° or 150° Fahr.; add the nitre, then the red powder, and lastly the smalt, till the whole forms a uniform paste. To make writing-paper matches, which burn with a bright flame, and diffuse an agreeable odour, moisten each side of the paper with tincture of benzoin, dry it, cut it into slips, and smear one of their ends with a little of the above paste by means of a hair-pencil. On rubbing the said end, after it is dry, against a rough surface the paper will take fire, without the intervention of sulphur.

To form lucifer wood-matches that act without sulphur, melt in a flat-bottomed tin pan as much white wax as will stand $\frac{1}{10}$th of an inch deep; take a bundle of wooden matches free from resin, rub their ends against a red-hot iron plate till the wood be slightly charred; dip them now in the melted wax for a moment, shake them well on taking them out, and finally dip them separately in the above viscid paste. When dry, they will kindle readily by friction.

The phosphorus may be introduced into the composition of lucifer matches in the form of a solution in bisulphide of carbon. It has been suggested by C. Puscher to employ a sulphide of phosphorus in the place of pure phosphorus.

A '*Safety Lucifer Match*,' as it is called, has been manufactured at Jönköping in Sweden and by Böttger in Germany. A patent was obtained in this country, by Messrs. Bryant and May, for this match. Its peculiarity consists in the division of the combustible ingredients of the lucifer between the match and the friction-paper. In the ordinary lucifer the phosphorus, sulphur, and chlorate of potash or nitre, are all together on the match, which ignites when rubbed against any rough substance. In the Swedish matches these materials are so divided that the phosphorus is placed on the sand-paper, whilst the sulphur and a minimum amount of chlorate or nitrate of potash is placed on the match. In virtue of this arrangement it is only when the phosphorised sand-paper and the sulphurised match come in contact with each other that the ignition occurs. Neither match nor sand-paper, singly takes fire by moderate friction against a rough surface. The phosphorus used in the sand-paper for these safety matches is the amorphous variety described below.

The preparation of lucifer matches has been attended with much human suffering. Every person engaged in a factory of this kind is more or less exposed to the fumes of phosphorus, and this exposure produces a disease which has thus been described by Mr. Harrison in the 'Quarterly Journal of Medical Science':—'This disease,' he says, 'is of so insidious a nature that it is at first supposed to be common toothache, and a most serious disease of the jaw is produced before the patient is fully aware of his condition. The disease gradually creeps on, until the sufferer becomes a miserable and loathsome object, spending the best period of his life in the wards of a public hospital. Many patients have died of the disease; many, unable to open their jaws, have lingered with carious and necrosed bones; others have suffered dreadful mutilations from surgical operations, considering themselves happy to escape with the loss of the greater portion of the lower jaw.'

By the introduction of an amorphous phosphorus discovered by M. Schrötter, which is in nearly all respects unlike the ordinary phosphorus, except in combustibility, but which answers exceedingly well for the manufacture of lucifer matches, this disease is prevented, the manufactory is rendered more healthy, and the boxes of matches themselves less dangerous.

Lucifer matches are now manufactured without sulphur. Letchford employs paraffin or paraffin-oil for saturating the wood: these ignite rapidly, and burn regularly with little or no smell. Notice and approbation are due to the persevering efforts which have been made to produce friction matches, containing neither ordinary nor amorphous phosphorus. Wiederhold has proved that lucifer matches of good quality may be made with chlorate of potash and hyposulphite of lead: a result which may prove most valuable, should experience show it to be attainable on the industrial scale. Other matches free from phosphorus have been made with the following mixtures, which are given by Jettel: chlorate of potash 4 parts, sulphur 1, and bichromate of potash, 0·4; or, chlorate of potash 7, sulphur 1, bichromate of potash 2, and nitrate of lead 2; or, chlorate of potash 8 parts, bichromate of potash 0·5, and sulphide of antimony 8. Wiederhold's mixture, mentioned above, may be made of chlorate of potash 7·8 parts, hyposulphite of lead 2·6, and gum-arabic, 1.

LUMACHELLA, or *Fire Marble.* This is a dark-brown shelly marble, having brilliant fiery or *chatoyant* reflections from within. See MARBLE.

LUNAR CAUSTIC. A name for nitrate of silver, when fused and run into cylindrical moulds.

LUPININE is a substance of a gummy appearance, so named by M. Cussola, because it was obtained from Lupines.

LUPULINE. The peculiar bitter aromatic principle of the hop, *Humulus Lupulus.* See BEER.

LUSTRING, sometimes spelled and pronounced *Lutestring*; a peculiar shining silk.

LUTE (from *Lutum,* clay; *Lut,* Fr.; *Kitte, Beschläge,* Ger.) is a pasty or loamy matter employed to close the joints of chemical apparatus, or to coat their surfaces, and protect them from the direct action of flame. Lutes differ according to the nature of the vapours which they are destined to confine, and the degree of heat which they are to be exposed to.

1. *Lute of linseed-meal,* made into a soft plastic dough with water, and immediately applied pretty thick to junctions of glass, or stoneware, makes them perfectly tight, hardens speedily, resists acids and ammoniacal vapours, as also a moderate degree of heat. It becomes stronger when the meal is kneaded with milk, lime-water, or solution of glue, and is the best lute for fluo-silicic acid.

2. Lute of thick gum-water, kneaded with clay, and iron filings, serves well for permanent junctions, as it becomes extremely solid.

3. By softening in water a piece of thick brown paper, kneading it first with rye-flour paste, and then with some potter's clay, till it acquire the proper consistence, a lute is formed which does not readily crack or scale off.

4. Lute, consisting of a strong solution of glue kneaded into a dough with new slaked lime, is a powerful cement, and, with the addition of white-of-egg, forms the *lute d'âne*—a composition adapted to mend broken vessels of porcelain and stoneware.

5. Skim-milk cheese, boiled for some time in water, and then triturated into paste with fresh-slaked lime, forms also a good lute.

6. Calcined gypsum (plaster-of-Paris), diffused through milk, solution of glue, starch, or gum-water, is a valuable lute in many cases.

7. A lute made with linseed, melted caoutchouc, and pipe-clay, incorporated into a smooth dough, may be kept long soft when covered in a cellar, and serves admirably to confine acid-vapours. As it does not harden, it may therefore be applied and taken off as often as we please.

8. Caoutchouc itself, after being melted in a spoon, may be advantageously used for securing joints against chlorine and acid vapours, in emergencies when nothing else would be effectual; or we may use 1 part of caoutchouc dissolved in 2 parts of hot linseed-oil, and worked up with pipe-clay (3 parts) into a plastic mass. It bears the heat at which sulphuric acid boils.

9. The best lute for joining crucibles inverted into each other is a dough made with a mixture of fresh fire-clay and ground fire-bricks, worked with water. That cement, if made with a solution of borax, answers still better upon some occasions, as it becomes a compact vitreous mass in the fire.

LUTEOLINE is the colouring-principle of the weld (*Reseda luteola*), a slender plant, growing to the height of about three feet, and cultivated for the use of dyers. When ripe it is cut and dried.

Chevreul was the first to separate the *luteoline.* It is extracted from the weld by boiling-water, and when this solution is concentrated and allowed to cool, the luteoline separates; it is then collected, dried, and submitted to sublimation, when it is condensed in yellow needles.

It is valued for its durability, and is used as a yellow dye, on cottons principally, and also on silks, but is little used at present. It was formerly used by paper-hanging manufacturers, to form a yellow pigment, but has been entirely superseded for that purpose by *quercitron bark* and *Persian berries.* It unites with acids and alkalis, the former making the colour paler, and the latter heightening the colour. The compound which it forms with potash is of a golden colour, becoming greenish when exposed to the air, by absorption of oxygen, and at length becomes red.

It forms yellow compounds with alum, protochloride of tin, and acetate of lead; with the salts of iron it produces a blackish-grey precipitate; and with sulphate of copper a greenish-brown precipitate.

It is readily soluble in alcohol and ether, but sparingly so in water.—H. K. B.

LUTIDINE, $C^{14}H^9N$ (**C^7H^9N**). A volatile nitryle base, discovered by Anderson in bone-oil. It has also been found in shale-naphtha, coal-naphtha, and in crude chinoline.

LYCOPODIUM CLAVATUM. The spores of the lycopodium, or club-moss, ripen in September. They are employed, on account of their great combustibility, in theatres, to imitate the sudden flash of lightning, by throwing a quantity of them from a powder-puff, or bellows, across the flame of a candle. They are sometimes known as 'vegetable sulphur.'

LYDIAN STONE, *Touchstone*, or *Basanite*. A flinty variety of jasper, used on account of its hardness, fine texture, and velvet-black colour, for trying the purity of the precious metals. The amount of alloy is indicated by the colour left on the stone after the metal has been rubbed across it.

LYELLITE. A basic sulphate of copper, occurring as a blue incrustation on killas, from certain Cornish mines. It is named after Sir Charles Lyell. According to Tschermak, it is a mixture of langite and gypsum.

LYNX. An animal producing a favourite fur of a greyish-white with dark spots. Most of the lynx-fur is imported from North America, and is obtained from the Canadian lynx (*Felis Canadensis*).

M

MACARONI is a dough of fine wheat-flour, made into a tubular or pipe form, of the thickness of goose-quills, which was first prepared in Italy, and introduced into commerce under the name of Italian or Genoese paste. The wheat for this purpose must be ground into a coarse flour, called *gruau semoule*, by the French, by means of a pair of light mill-stones, placed at a somewhat greater distance than usual. This *semoule* is the substance employed for making the dough. See VERMICILLI.

MACE is a somewhat thick, tough, unctuous membrane, reticulated, and of a yellowish-brown or orange colour. It forms the envelope of the shell of the fruit of the *Myristica moschata*, the nutmeg. It is dried in the sun, after being dipped in brine; sometimes it is sprinkled over with a little brine, before packing, to prevent the risk of moulding. Mace has a more agreeable flavour than nutmeg, with a warm and pungent taste. It contains two kinds of oil: the one of which is unctuous, bland, and of the consistence of butter; the other is volatile, aromatic, and thinner. Mace is used as a condiment in cookery, and the aromatic oil occasionally in medicine. See NUTMEG.

MACHINES FOR THE CUTTING OF COAL IN MINES. The severe character of the labour of the coal-miner, and the dangers connected with his employment have led to several mechanical appliances, by which the task of 'hewing coal' might be lessened, and the dangers attendant on the work diminished. No one has given more attention to the subject than Mr. William Firth of Leeds, to whom we are indebted for one of the very first machines which have been successfully employed in the cutting of coal in mines. To this gentleman we owe the following notice of the progress made within the past century in this direction:—

'In 1761 Michael Menzies of Newcastle obtained a patent for cutting coal in mines, and that is the earliest evidence which we have of any attempt having been made to produce a mechanical coal-cutter; and his plans having regard to the *time* at which they were produced, were remarkable for their ingenuity.

'Menzies' specification is also remarkable in other respects, as showing that it was his intention to make use of the 'fire-engine' as his motor; which engine had, about two years previously, through the improvements of Watt and of Smeaton, attained only to so much perfection as to become a doubtful rival to the 'water miln' or 'wind miln,' and the 'horse gin.'

'By the power of one or other of these agents, he proposed to give motion to a heavy iron pick, made to reciprocate by means of spears and chains, carried down the pit, and with wheels and horizontal spears, on rollers, extended to the working places, and there to "shear" the coal exactly as it is now performed. In the same patent, Menzies included a "saw" to cut the coal; and although nothing came from his labours, he displayed so much mechanical knowledge, as to have deserved success; and his failure was evidently due to the absence of an eligible power, and not to his deficiencies as a mechanic.

'During the hundred years that followed these events more than a hundred other patents were applied for, and granted; but amongst them all, there was not one machine that approached nearer to success than the invention of Michael Menzies.

'This fact is not referred to in disparagement of the patentees, for there were many curious devices, ingeniously arranged; but the matter is referred to to show that the object excited much continuous interest, and that amongst so many miscarriages, our mechanics were still hopeful.

'Amongst these devices may be enumerated the "saw," "catapult," "battering ram," "plough," "rotary wheel," "endless chain," "planing machine," and many others by which the coal was to be either crushed, cut, or shared out.

'There had been no suitable power made known for driving the machines; and it was to that cause, without doubt, that so many failures and disappointments were attributable. The steam-engine, even when it attained to its most perfect form, is not in itself sufficient for the purpose, because steam cannot be produced near to the place where the work has to be done, nor can it be carried long distances in an effective condition, by reason of its rapid condensation. Moreover, an escape of exhaust-steam could not be permitted in the coal-mine, because of its tendency to soften and bring down the roof, the difficulty of maintaining which is already the most serious and troublesome part of coal-mining operations.

'Hydraulic power might, in certain cases, be, and has been recently, tried, but its unfavourable conditions exceed its advantages for the purpose of cutting coal in mines, and may be put aside from present considerations.

'But in compressed air, in so far as the moving power is concerned, every requirement is found; and from the date of the experiments made at West Ardsley in Yorkshire, in 1862, the question was undoubtedly settled.

'The elastic property of air under compression, is an old and well-known power; but until these experiments had been completed, its value was but imperfectly understood, and its future beneficial influence on coal-mining was unappreciated.

'The engine for compressing the air, by which a coal-cutting machine is worked, is generally placed on the surface, near to the top of the shaft; a receiver is fixed in close proximity thereto, and the air is taken from the compresser to the receiver, which is 30 feet in length and 4 feet in diameter.

'The density is generally of about three atmospheres.

'Iron pipes of sufficient area are laid on from the receiver to the bottom of the shaft, and there, being split into smaller sizes, is led in every needed direction through the roads and passages of the mine, exactly as the gas and water services are laid on in any town.

'At the entrance into the working places, screw joints or stop-cocks are fixed to the iron air-pipe, at which point an india-rubber nose, 50 or 60 yards in length (as the length of the "benk" may require) is screwed on; the other end of the nose is attached to the cutting machine, and when all is in readiness, the tap at the receiver is turned on, and the air rushes down, and throughout the whole service of pipes.

'The air does not require to be forced from the receiver, for by its own elasticity it is carried forward at a velocity corresponding to its own density.

'Apparently it loses, if the arrangements are good, but little of its power by distance, except the frictional retardation; and machines are working underground, at nearly two miles distance from the air-engine, without any serious loss of force.'

Firth's Coal-Cutting Machine.—A machine which may be simply described as a pick placed horizontally, and worked by a crank motion, has for some five or six years (1874) been steadily at work in the West Ardsley collieries. The colliers, who at first objected to 'following the machine,' instead of working with their old implements, have at length yielded to the evident advantages of the 'coal-cutter,' and in many of our largest collieries these machines are now fairly introduced.

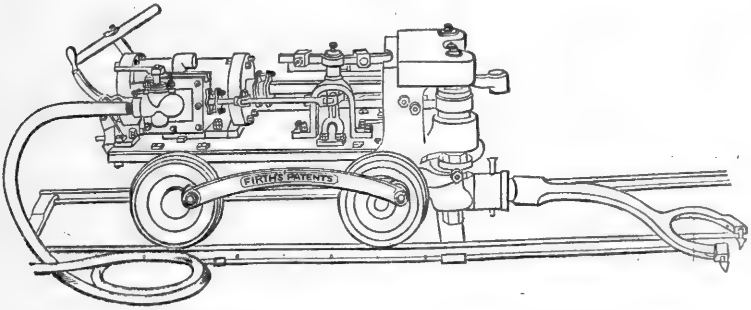
We must now turn to the consideration of this machine for cutting the coal, as invented by Mr. William Firth. *Fig.* 1413 shows its form and construction; the weight is about 15 cwts. for an ordinary sized machine, its length 4 feet, its height 2 feet 2 inches, and a gauge 1 foot 6 inches to 2 feet; it is very portable, and easily transferred from one 'benk' to another.

The front and hind wheels of the machine are coupled together in a similar manner to the coupled locomotive engines. The 'pick' or cutter is double-headed, whereby the penetrating power is considerably increased.

The groove is now cut to a depth of 3 feet to 3 feet 6 inches at one course, whereas by the old form of a single blade, the machine had to pass twice over the face of the coal to accomplish the same depth. The points are loose and cottered into the boss, so that when one is blunt or broken, it can be replaced in a few minutes. It dispenses with the necessity of sending the heavy tools out of the pit to be sharpened, and is an immense improvement on the old pick.

When all is in readiness for work, the air is admitted to the machine, and the reciprocating action commences. The piston works at a speed of sixty to ninety strokes per minute, varying according to the density of the compressed air, the hardness of the strata to be cut, or the expertness of the attendant.

1413



As to the quantity of *work*. In 'long-wall,' a machine can, under favourable circumstances, cut 20 yards in an hour, to a depth of 3 feet; but we consider 10 yards per hour very good work, or say 60 yards in a shift.

This is about equal to the day's work of twelve average men, and the persons employed to work the machine are one man, one youth, and one boy, who remove and lay down the road and clear away the *débris*.

The machines are built so strong that they rarely get out of working condition. Some of those now working at West Ardsley (and other places), have been in constant use for three or four years.

At that colliery there are about eight machines in use. One of the seams is so hard and difficult to manage, that it could not be done 'by hand,' and the proprietors had to abandon it, but *now*, by the employment of these machines, it is worked with perfect ease. It is a thin cannel seam, with layers of iron-stone, and the machines now 'hole' for about 1,200 tons per week.

The groove made by the machine is only 2 or 3 inches wide at the face, and 1½ at the back, whereas by hand, it is 12 to 18 inches on the face, and 2 to 3 inches at the back, thus:—

In thick seams worked by hand, the holeing is often done to a depth of 4 feet 6 inches to 5 feet, and the getter is quite within the hole he has made, and where the coal does not stick well up to the roof, or where there is a natural parting, there is great difficulty and danger from falls of coal. In cutting coal by the ordinary method, the angle is such that when the upper portion of coal falls off from the roof, that it must pitch forward into the 'road,' but by the machine cutting a perfectly horizontal groove. The coal, having lost its support, simply settles upon its own bed; and has no tendnecy to fall forward.

The following statement was made by the inventor at the meeting of the British Association at Bradford:—

'The cost of applying coal-cutting machinery is an important part of the question, but it frequently happens that at old established collieries there may be surplus power, which can be utilised; but supposing that everything has to be provided new, then the following may be taken as an approximate estimate of the necessary outlay:—

	£
2 Boilers at 500*l.* each	1,000
1 Steam-engine	1,250
10 Machines at 150*l.* each	1,500
Pipes, Receivers, Fixings, and sundry other outgoings	1,250
	say 5,000

'This outlay would provide all necessary power and plant for the regular working of eight machines, with two in reserve; and estimating that each machine will cut 60 yards per day, the product in a 4-foot seam would be 85 tons per day, or per week say 500 tons per machine, and 8 by 500 is 4,000 tons.

'Now at this rate of expenditure and work done, an allowance of 2*d.* per ton would in three years liquidate the entire outlay.

'But there is no reason why the machines should be restricted to a single shift daily; indeed, it is far more economical to work double shifts, there is no additional outlay of capital, and so far as depends upon the machinery, the output might be easily increased to 8,000 tons per week.

'We now come to the relative costs of cutting the coal, by hand and by *machine*, and the following figures may be taken as representing a somewhat favourable state of things for the latter.

'The seam is the "Middleton Main" or "Silkstone Bed." The depth of the mine is 160 yards, and the coal four feet thick; there are two bands of shale, with a thin layer of coal between them.

'The bottom portion is not always wholly merchantable, but when it is so, it yields one ton and a third of a ton per running yard. For the purpose, however, of this comparison, I take 60 tons only per day (which would come out of 45 yards of machine working.'

All cut on the end.

The Cost by Hand.

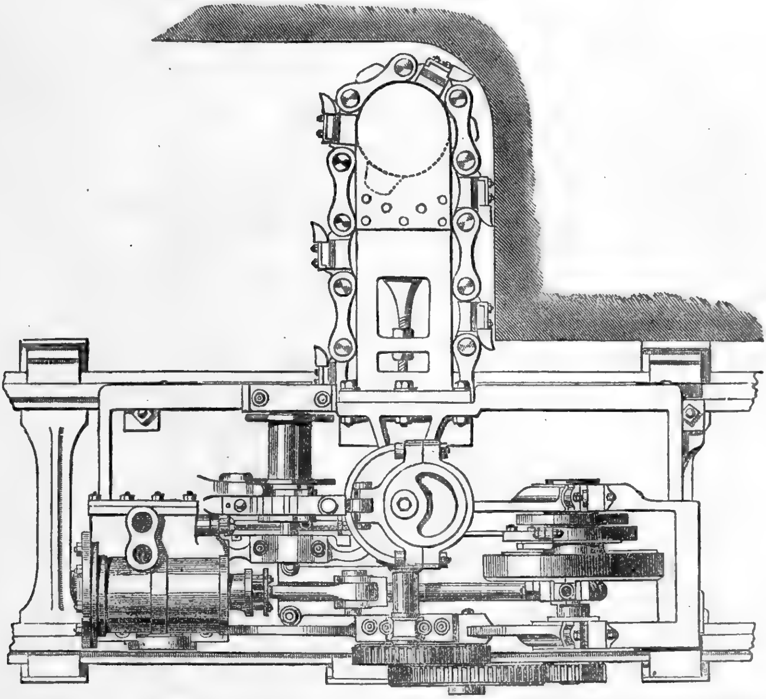
	£	s.	d.	£	s.	d.
30 Men cutting, filling, timbering, drilling, road-laying, blasting, and all other needful work ready in the corves for the "hurrier," at 4*s.* 5¾*d.* per ton				13	8	9
By Machine.						
1 Machine man at 8*s.* 6*d.*	0	8	6			
1 youth at 5*s.* 6*d.* } equal to 1 man	0	5	6			
1 boy at 3*s.* 6*d.*	0	3	6			
3 men clearing and packing at 8*s.* 4*d.*	1	5	0			
6 men filling, 10 tons each man at 8¼*d.* per ton	2	1	3			
3 men timbering at 6*s.* 10*d.*	1	0	6			
⅛th portion of cost of steam and air expenses	1	14	0			
Maintenance at 1*d.* per ton	0	5	0			
Redemption of capital at 2*d.* per ton	0	10	0			
	8	13	9			
Difference in money in favour of the machine: or 1*s.* 7*d.* per ton	4	15	0			
				13	8	9

It is necessary now to bring under notice some of the other coal-cutting machines which have been introduced of late years.

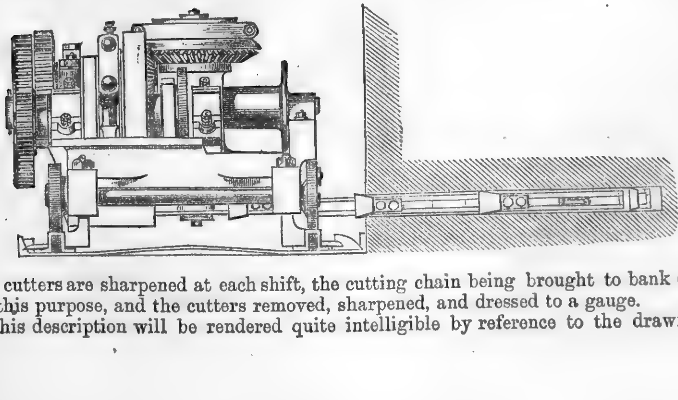
Baird's, or the Gartsherrie Machine.—One of the machines which has claimed the largest share of attention is the 'Gartsherrie coal-cutter' of the Messrs. Baird. This appears to be a modified form of a machine which was patented many years since by Mr. Gleadhill.

The cutting in these machines is done by an endless chain with cutters attached, driven round a jib or arm, which extends underneath the coal. The machine is actuated by air compressed on pit bank to 35 or 40 lbs. per square inch, and conveyed therefrom in cast-iron pipes. The machine at work draws or "feeds" itself along the coal face, with the jib projecting underneath the coal 2 ft. 9 in. or 3 ft. as required. The present work done (1874) is 300 to 350 ft., cut 2 ft. 9 in. deep, in a shift of eight to ten hours, and as the seam worked is 2 ft. 10 in. thick, this yields 75 to 90 tons. This rate includes all stoppages, and, of course, if it were possible to drive along without interruption, the figures would be very much higher. The speed also is capable of considerable increase by extra pressure of air, and when it is stated that even in the hard Gartsherrie coal the machine has frequently been timed at about 6 ft. in four minutes, an idea may be formed of what it would do in soft English coal with a good pressure above. The machine at work is attended by three men. The working parts of the machine are carried upon a strong cast-iron soleplate 6 ft. long by 2 ft. 6 in. broad, set upon four wheels. On the soleplate is bolted the cylinder, 8½ in. in diameter, with a 12-in. stroke. The crank shaft is fixed in bearings cast on soleplate. On this shaft is the fly-wheel and excentric, which is reversible. On one end of the shaft, overhanging the soleplate, is attached a spur-wheel, which by means of another shaft and bevel-gearing, is connected to an upright shaft, on under end of which is the chain-wheel, communicating motion to the cutting chain. The whole of these wheels are of Bessemer steel, and, so far as proved, appear to give the greatest satisfaction in wear. The cutters, nine in number, and 2¾ in. broad on face, are secured to the chain by means of two bolts passing through cutter and link. The jib, which distends the chain, is bolted to side of soleplate, and consists of two parts, the stock and point, adjustable by means of a nut and screw working against a bridge in stock. The chain is made of wrought steel, and the cutters of the best tool-steel. The machine draws or "feeds" itself by means of a drum and a $\frac{5}{16}$ in. chain passed round a pulley fixed to a prop 100 ft. in advance. The drum shaft is actuated through a toothed wheel worked by a racket motion from an excentric cast or bevel-wheel of upright shaft. The roadway on which the machine travels is of cast malleable iron. The rails are keyed down to sleepers, and are kept in condition by means of snugs cast on sleepers, which fit into oblong holes in end of rails. Each machine is fitted with 21 ft. or seven pairs of such rails 3 ft. long. The machines are of two designs. No. 1, being 2 ft. 4 in. high, requires about 3 ft. of head room between pavement and roof. No. 2 is 1 ft. 8 in. high, including roadway, and so is capable of working the thinnest seam. The gearing can be altered to speed required by the nature of the coal or other material cut. They have been adapted to undercut clay band iron-stone lying on hard sandy fire-clay. At work the machine is attended by three men, one driving, one lifting roadway behind machine, and the other laying roadway in front, &c.

1414



1415

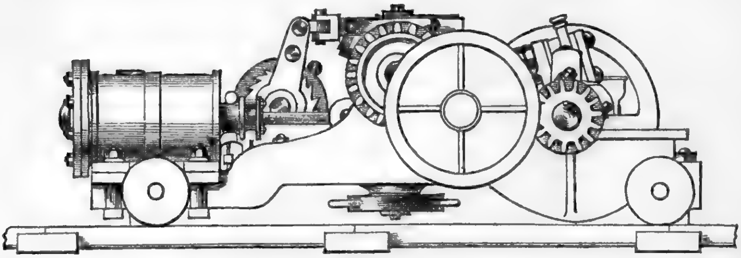


The cutters are sharpened at each shift, the cutting chain being brought to bank daily for this purpose, and the cutters removed, sharpened, and dressed to a gauge.

This description will be rendered quite intelligible by reference to the drawings.

Fig. 1414 shows the Gartsherrie machine in plan. *Fig.* 1415 gives an end elevation of the machine. In both cases the way in which the cutting work into the coal is effected is clearly shown. In *fig.* 1416 a side elevation is given, from which it will be easy for anyone having but a slight acquaintance with machinery to see how motion is given to the cutters.

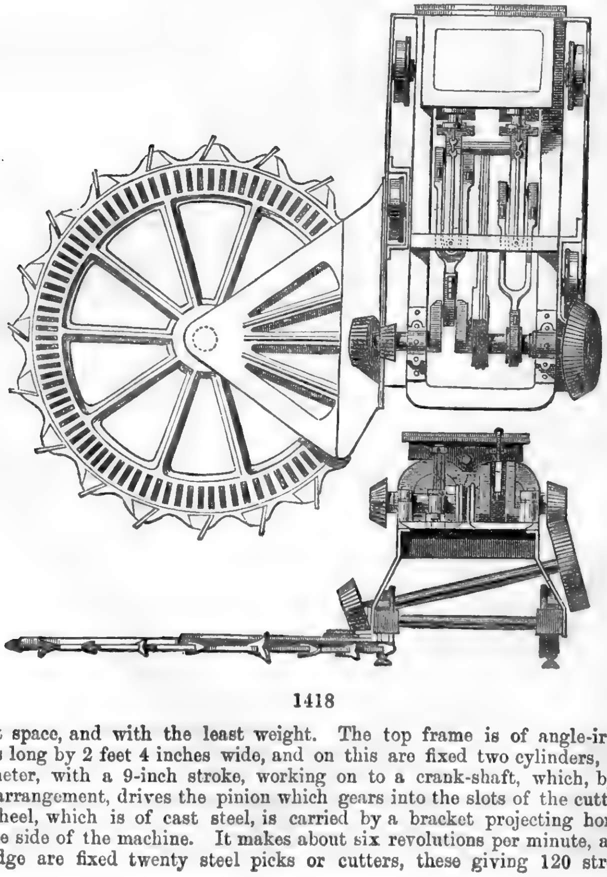
1416



Gillott and Copley's Machine, which is shown in the accompanying woodcuts, was patented in 1868. *Fig.* 1417 gives the machine in plan.

The machine, with the exception of the cylinders and one spur-wheel, is made entirely of steel and wrought iron, thus combining the greatest strength in the smallest space, and with the least weight. The top frame is of angle-iron, 4 feet 9 inches long by 2 feet 4 inches wide, and on this are fixed two cylinders, 7½ inches in diameter, with a 9-inch stroke, working on to a crank-shaft, which, by a very simple arrangement, drives the pinion which gears into the slots of the cutter-wheel. This wheel, which is of cast steel, is carried by a bracket projecting horizontally from the side of the machine. It makes about six revolutions per minute, and on its outer edge are fixed twenty steel picks or cutters, these giving 120 strokes per

1417

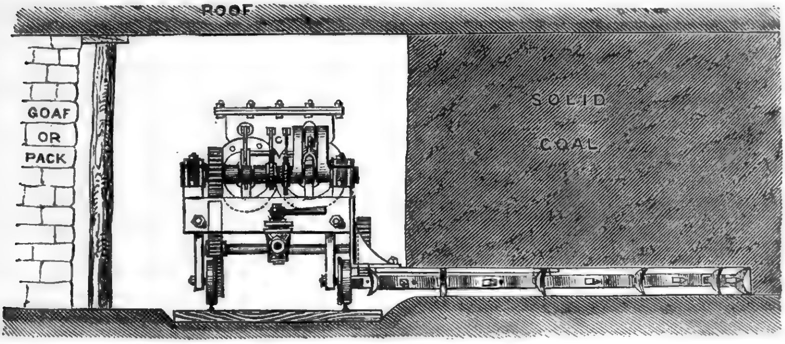


1418

minute; it is 3 feet 10 inches in diameter, and makes a clean cut of 3 feet 4 inches deep by 3 inches thick, and from this space it entirely sweeps out the whole of the coal as it revolves. The machine is propelled by a wire rope having one end secured at the extremity of the face, and passing round a drum driven by the air-cylinders, or by hand-gearing attached to the side of the machine. The whole is covered in with a moveable sheet-iron casing to protect it from anything falling from the roof. One man only is required to be in attendance on the machine, and another should follow to sprag the coal as it is cut.

With a pressure of 27 lbs. of compressed air per square inch the machine has holed, in a hard tough fire-clay seating, 25½ yards in 40 minutes, and 24 yards 1 foot of strong solid coal in 55 minutes, with only 20 lbs. pressure. A fair average rate of work with 27 lbs. pressure may be stated at thirty yards per hour, 3 feet 2 inches to 3 feet 4 inches under and 3 inches thick, either in a seating or moderately hard coal. The average rate of holeing by manual labour in the seam where it is now working is about 7 yards for a day's work—equivalent to about nine men working a whole day to do what the machine does better in two hours. The men have only to wedge or shoot the coal down and clear it away, while the machine is taken to another bank to do its work there. In *figs.* 1418 and 1419 the machine is shown in sectional elevations.

1419



Winstanley's Machine,—The coal cutting machine of Messrs. Winstanley and Barker is not essentially different from the machines already described. It consists of a small frame running upon four wheels adapted to the colliery gauge, and carrying two oscillating cylinders driven by compressed air or steam. On the crank-shaft and underneath the frame is a pinion which gears into a very coarse-pitched toothed wheel, the ends of the teeth being armed with cutters. This cutting wheel can be turned under the carriage when not required, and when placed in position is brought to bear against the coal by turning a handle into which it cuts, until the arm carrying the wheel is at right angles to the carriage. The machine is slowly dragged forward by means of a chain attached to a crab and worked by a boy. As the machine advances, the miner in attendance drives wooden wedges into the cut to support the coal, and when the machine is out of the way the wedges are withdrawn and the coal falls. The machine itself only weighs 15 cwts., and will cut at the rate of 30 yards per hour with a pressure of only 25 lbs. per square inch, making a 'holing' in the coal 3 feet deep and only 2¾ inches high. The height of the machine is only 22 inches. It has the disadvantage of being only able to cut on one side of the carriage, but of course it can be constructed to cut on the right- or left-hand side as may be desired by the purchaser.

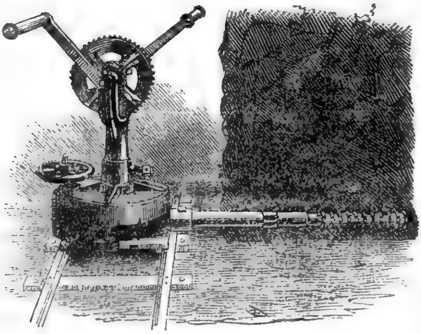
Hurd and Simpson's 39-inch self-acting, right and left-hand, variable height coal-cutter was specially constructed for the Glass Houghton Coal Company to undercut in the blue stone band lying between two portions of the coal-seam. This machine is worked on a somewhat similar principle to that of Winstanley and Barker; that is to say, the coal is undercut by means of a *circular saw* working at the end of a moveable lever, but with this important difference, that in Hurd and Simpson's machine the cutter is placed in front, and can thus cut the coal right ahead of the machine or on either side of it. The cutting wheel is slightly excentric, and the machine hauls itself along by means of a chain anchored ahead of it; for as the cutter revolves, being an excentric, the teeth on one portion of the periphery would revolve without touching the coal, but at this time the self-acting hauling gear comes into play, the machine advances, and the cutters get a fresh feed on the coal. This coal-cutter is 30 inches high over all, and cuts to a depth of 3 feet 3 inches.

Brown's Monitor Coal-Cutter has excited some attention in America. The machine consists of a five horse-power steam-engine driven by steam carried into the mine by a steam-pipe, terminating, however, in a few feet of rubber-hose, which permit of full freedom of motion to the machine. The intention of the proprietors is to employ compressed air in place of steam eventually. The cutting arrangement is an iron rim of four feet in diameter, which has on its periphery moveable steel teeth, placed at points about 12 inches apart. These teeth may be taken out and ground whenever they become dull. This rim lies on small wheels which support it and allow a free motion, and has cogs on its under surface which gear into cogs on a shaft turned by the engine. By this means the power is applied near the circumference of the wheel, instead of at the centre as in the ordinary circular saw. The principal reason for this arrangement is to get a deeper cut at the coal. The cutter can be put to a depth of $3\frac{1}{3}$ feet, or $\frac{7}{8}$ths of its whole diameter, whereas the ordinary circular saw can hardly cut to one-half of its diameter. The machine runs on a moveable track, and is fed by means of a screw working in cogs. The track is put down along the side of the coal at the proper distance from it, and when a cut has been made the whole length, the machine is put on tracks and wheeled to the next 'room,' where the track is laid as before, and so on through the mine. The duty of the machine is calculated to be at about a yard in five minutes.

The estimate of its economy given by the proprietors is that it saves about 35 cents per ton over the cost of putting out coal by hand labour, which in a mine turning out, say 200 tons a day, amounts to a saving of 70 dollars per day. The first cost of the machine is very moderate, being only about 800 dollars.

Jones's Hand Coal-Cutter.—This machine is practically a combination of inclined circular-saws mounted upon a revolving rod, so that the groove cut by each saw runs into the groove cut by the next, thus thoroughly under-cutting a seam. The saws are set on the rod obliquely, and provision is made for retaining them at a proper distance from each other, and in the most suitable position on the rod, the end of which has a screw-thread cut upon it, by means of which it is fastened into the spindle and bearings. Another form of cutting apparatus may be formed from a flat bar of steel, with saw teeth along both of its outer edges, and so twisted that the toothed edges are formed into spirals (*fig.* 1420). By this arrangement, which resembles that of Macdermott's rock-perforator, the cutter readily clears itself from the slack which it cuts away. See **Rock-Perforator**. A revolving cutter of this kind may be worked in two ways. It may be caused to sweep in the arc of a circle into and out of the coal, so as to cut out a groove in it, the spindle of the cutter being for that purpose carried by a frame turning upon an axis, such axis being also traversed forward from time to time in a line parallel with the face of the coal operated upon. Alternatively the frame carrying the spindle of the cutter may simply be caused to move forward continuously in a line parallel with the face of the coal, in which latter case a groove will be produced of a depth equal to the length of the cutter. But if the cutter is caused to sweep round in the arc of a circle, a groove of any desired depth can be cut, irrespective of the length of the cutter itself.

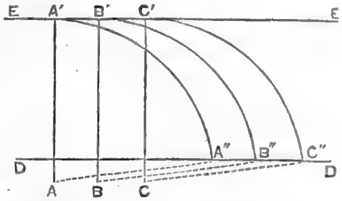
1420



Revolving cutters, such as above described, can be driven either by hand-power or by compressed air. In the former case, and when the machine is to be used only for holing or undercutting, the following is proposed as the preferable arrangement. The spindle of the cutter is mounted on bearings in a frame which can turn upon a stud on the bed-plate of the machine. On the under side of this bed-plate are sledge runners to run on rails laid upon the floor of the mine. On the frame which carries the cutter spindle is a toothed arc, into which gears a pinion carried in bearings from the bed-plate. The pinion can be turned by a hand wheel on its spindle, and thus the cutter can be caused to sweep round to and fro in the arc of a circle. Upon the cutter spindle is fixed a bevel pinion gearing into a horizontal bevel wheel, which is concentric with the stud upon which the frame carrying the cutter is mounted. The horizontal bevel is mounted upon a vertical shaft, upon which is a fly-wheel, and at its upper end a pinion which gears with a bevel wheel, which latter can be driven by a crank handle, and thus a quick revolving motion can be given to the cutter, whilst that, at the same time, may be freely swept round to and fro in the arc of a circle. Means are provided for the exclusion of dirt from the machinery, and for holding the apparatus securely while the cutter is in motion. An adjustment may be made for cutting grooves, either vertically or horizontally in the upper part of the seam, and in such case the spindle of the cutter is driven by a rotary engine set in motion by compressed air.

The mode of action of Mr. Jones's apparatus will be more clearly understood on reference to the diagram (*Fig.* 1421). The fixed end of the cutter is supposed to be successively at A, B, and C, the seam of coal lying between the lines D D and E E. First the cutter, starting from the position A A′, travels round to the position A A″, clearing the triangular space A A′ A″. Then the fixed end is transferred from A to B, when a quarter revolution changes its direction from B B′ to B B″, clearing the space B B′ B″, and on removal to the fixed point C, the similar space C C′ C″ is cleared.

1421



Bidder's Machine for breaking down Coal.—Mr. S. P. Bidder, jun., had, in conjunction with Mr. John Jones, devised a machine which had been submitted to actual trial on a working scale at the Harecastle Colliery, where the results were so satisfactory as to induce the proprietors to make arrangements for its immediate adoption. The machine consisted of a small hydraulic press of 12 tons power, to which was attached a pair of tension-bars, bent in the form of a connecting rod or hinge-strap. These were placed one over the other in the bore-hole, and between them, at the extreme end, there were a clearance-box and two metal pressing-blocks, between which was forced, by the action of the hydraulic press, a split wedge 15 inches long, causing a lateral expansion of 3 inches. The ram was then withdrawn, and a second wedge was inserted between the two parts of the first wedge, and was forced up until sufficient expansion was obtained to break the coal. The operation could be repeated several times if found necessary. The whole apparatus would weigh about 50 lbs. The hydraulic press was in future to be made of steel, and the ram would be cored out. In practical working, each gang of colliers would be provided with the tension-bars and three wedges, while the presses would be under the charge of the men who at present occupied the position of firemen, so that no new class of labour would be introduced, while the risk of firing would be got rid of. Trials had been made both in the 7-feet and the 9-feet seams at Harecastle; and in the latter, with three wedges, about 12 tons of coal had been brought down in only three or four pieces. It was found that the press could be applied, and the blocks brought down, in less time than was consumed by firing a hole and waiting for the smoke clearing.

Explosions in mines were known to arise, very frequently, from the employment of gunpowder for blasting. In the interests of humanity alone, an efficient substitute had long been desired by practical men; and this, it was believed, had been accomplished by Bidder's machine, which had also the advantage of preventing the waste of coal incurred by the present system.

The following remarks, made by Mr. W. Menelaus of Dowlais, on the use of coal-cutting machines in the collieries of South Wales, are so much to the point that they are extracted from the 'Journal of the Institution of Mechanical Engineers.' These remarks have reference more especially to the coal-cutting machine of Mr. Robert Winstanley.

Mr. Menelaus said that, having paid considerable attention to the subject of coal-cutting by machinery, and watched carefully the several plans that had been tried, he had not yet found any machine that could compete with colliers' labour under the exceptional circumstances attending the working of the thick veins of coal in South Wales. The holing of the coal constituted there only one-tenth of the entire labour in the collieries; and the margin for saving upon this portion of the work was therefore so small, that he had given up as hopeless the introduction of coal-cutting machines in that district. The colliers at present worked only one turn of about 8 hours per day of 24 hours; and the coal was all brought down by natural pressure during the interval while the men were all absent, the bulk of the coal being obtained with very little holing. If three turns were worked per day he was not sure that the holing might not be advantageously done by a machine, even in the thick soft veins of the South Wales collieries; and in such a case, he should be very glad to adopt machines for the purpose. In thin veins of hard coal he considered the introduction of coal-cutting machines would be attended with very great advantages, and he hoped they would be generally adopted, and thought every possible endeavour should be made to establish their use. The machine now described appeared to him to be one of the best that had been brought forward for coal-cutting; and he thought the principle of its construction and action was more likely to prove the right one than that of machines designed to work a pick in a similar manner to hand-labour. One of the earliest coal-cutting-machines that he remembered had been made on the same principle as a circular saw, but in that case the cutting-wheel had been literally a circular saw with fixed teeth, and had consequently proved a failure in actual working. The use of moveable teeth in the cutting-wheel of the present machine was an important practical improvement, and this machine appeared to him to have been worked out in a very ingenious way, and seemed one of the most likely to succeed that he had yet met with. Whether the air was worked expansively in the cylinders was a question that should not be overlooked in regard to the economy of any coal-cutting machine; and if the expansion could be obtained without complicating the construction of the machine, it was by all means desirable to have the benefit of it. If, however, it involved the introduction of cams or excentrics and ordinary valve-gear, he thought it would be better to waste a portion of the power than to introduce these complications, as he considered the utmost simplicity of construction was an object of such essential importance for the success of a coal-cutting machine; and in working with compressed air it must be borne in mind that the power was cheaply produced at the mouth ot the pit, and readily conveyed to the machine. The construction of the machine now described seemed to possess the advantage of simplicity, and he thought this machine was very likely to prove one of the best yet introduced; it had also another advantage in being able to hole its own way into the coal at starting, without requiring any preliminary holing to be done by hand before it could be got to work. He agreed in considering that the discharge of exhaust-air from a coal-cutting machine was hardly capable of producing an appreciable effect upon the ventilation of a colliery, as the quantity of fresh air so discharged was insignificant in comparison with the total quantity passing through the mine.

MACLE is the name given to certain spots in minerals, of a deeper hue than the main substance, and differing from it. Clay-slate may be macled with Iron Pyrites; —or it may be that the macle spots are some peculiar form of the same mineral matter supposed to proceed from some disturbance of the particles in the act of crystallisation. *Macles* are twin crystals which are united, or which interpenetrate.

MADDER (*Garance*, Fr.; *Krapp*, *Färberröthe*, Ger.), a substance very extensively used in dyeing, is the root of the *Rubia tinctorum*, Linn. It is employed for the production of a variety of colours, such as red, pink, purple, black, and chocolate.

The *Erythrodanum* or *Ereuthrodanum* of the Greeks, of which Pliny says that it was named *Rubia* in Latin, and that its roots were used for dyeing wool and leather red, was probably identical with the *Rubia tinctorum*, since the description of its appearance and uses given by ancient authors can hardly apply to any other plant. It was cultivated in Galilee, Caria, and near Ravenna in Italy, where it was planted either among the olive-trees or in fields destined for that purpose. Another species of Rubia, viz. the *R. manjista*, grows in the mountainous regions of Hindostan, and the roots of this and an allied plant, the *Oldenlandia umbellata*, called by the natives *Chaya*, have been in use in that country since the most remote period, for the purpose of producing the red and chocolate figures seen in the chintz calicoes of the East Indies. (See CALICO-PRINTING.) The peculiar process by which the colour called Turkey red is imparted to cotton was probably invented originally in India, but the dyeing material generally employed in this process was not madder, but the chaya-root. From India the art of dyeing this colour seems to have been carried to Persia, Armenia, Syria, and Greece; where it was practised for many centuries before it became known in the western part of Europe. In those countries, however, the root of the *Rubia peregrina*, called in the Levant *Alizari*, was the material to which dyers had recourse for this purpose, and large quantities of it are at the present day imported into Europe from Smyrna, under the name of *Turkey roots*. In the middle ages, according to Beckmann, madder went by the name of *Varantia* or *Verantia*. The cultivation of madder was introduced into the province of Zeeland, in Holland, in the reign of the Emperor Charles V., who encouraged it by particular privileges conferred on the inhabitants for the purpose. According to Macquer, however, it was to the Flemish refugees that the Dutch were first indebted for their knowledge of the method of preparing the plant. It is still grown very extensively in that part of Holland, and large quantities are annually exported thence into other countries. Until very recently indeed, the dyers of this country derived almost the whole of their supply of madder from Holland; and it was the discovery that Dutch madder was incapable of producing some of the finer colours more recently introduced, that first led to its being to some extent supplanted by madder grown in other countries.

In the district of Avignon, in France, the cultivation of the plant commenced about the year 1666, under Colbert, but it was chiefly by the efforts of the Secretary of State, Bertin, towards the close of the last century, that it became firmly established there. The French dyers and printers are supplied with madder from Avignon and Alsace, and large quantities are also exported from France into England and other countries. Madder is also grown for the use of dyers in Silesia, Naples, and Spain. It was formerly more extensively cultivated in England than it is now, when it can be imported at a less expense than it can be raised. The *Rubia peregrina* grows wild in the south of England, but it is not applied to any useful purpose.

The *Rubia tinctorum* is one of the least conspicuous and ornamental of our cultivated plants. In external appearance it bears great resemblance to the ordinary bed-straws or Galiums, with which it is also botanically allied. Some species of galium seem also to contain a red colouring matter, and one of them, the *G. verum*, is used in the Hebrides for dyeing. The *R. tinctorum* belongs to the class Tetrandria, order Monogynia, of the Linnæan, and the order Rubiaceæ, of the Natural system. It is a perennial plant, but has an herbaceous stem, which dies down every year. The main part of the root, which extends perpendicularly downwards to a considerable depth, is cylindrical, fleshy, tolerably smooth, and of a pale carrot colour. On cutting it across transversely, it is found to consist externally of a thin cortical layer, or epidermis, to which succeeds a thick, spongy mass of cellular tissue, filled with a yellow juice, and in the centre runs a thin tough string of woody fibre, of a rather paler yellow colour than the enveloping cellular tissue, which may easily be peeled off. The root when freshly cut has a yellow colour, but speedily acquires a reddish tinge on exposure to the air. Many side roots issue from the upper part or head of the parent root, and they extend just beneath the surface of the ground to a considerable distance. It in consequence propagates itself very rapidly, for these numerous side roots send forth many shoots, which, if carefully separated in the spring, soon after they are above ground, become so many plants. From the roots spring forth numerous square-jointed stalks, which creep along the ground to the length of from 5 to 8 feet. Round each joint are placed in a whorl from 4 to 6 lance-shaped leaves, about 3 inches in length, and almost an inch wide at the broadest part. The upper surface of the leaves is smooth, but their margin and keel, as well as the four angles of the stem, are armed with reflexed prickles, so as to cause the plant to adhere to any rough object with which it comes in contact. The flowers, which are yellow, are arranged in compound panicles, which rise in pairs opposite to each other from the axils of the leaves. The calyx is very small. The corolla is small, campanulate, and 5-cleft. The flower contains 4 stamens, and 1 style. The fruit or berry is at first red, but afterwards becomes black. It consists of two lobes, each of which contains a seed.

The *Rubia tinctorum* thrives best in a warm climate, and if grown in the north of Europe a warm sheltered situation should be chosen. A deep, dry soil, containing an abundance of humus, is best adapted for its cultivation. A rich loam, in which there is a large proportion of sand and but little clay, is preferable to the stiffer soils. As the plant requires to be left in the ground several years, it is not one which can be adapted to any system of rotation of crops, and its cultivation must be carried on independently. Land which has lain for a considerable time in grass is preferred to any other for the purpose. At all events, it is well not to allow it to follow on root crops. The finest qualities of madder grow in calcareous soils. In the district called *Palud*, which produces the best quality of French madder, the soil contains about 90 per cent. of carbonate of lime, and is moreover capable of yielding several successive crops of the plant; whereas the land which grows the second quality called *rosée* is richer, but less calcareous, and can only be made to grow madder alternately with other crops. The land must be well dug up with the spade about the beginning of autumn, and before winter. The manure used must be well rotten, and mixed with earth in a compost some time before it is used. Good stable-dung, which has heated to a certain degree and been turned over two or three times before it is mixed with earth, is the best. The dung should be put in layers with the earth, and if the whole can be well-watered with urine or the drainings of the yard, and then mixed up by the spade, the compost will be much superior to fresh dung alone. The manure having been dug or ploughed in, the land is left over winter, and in spring it is turned over again, in order to destroy all weeds, and make the soil uniform to the depth of 2 feet at least. After having been harrowed flat it is ready for planting. Madder is generally grown from suckers or shoots, rarely from seeds. The shoots are prepared by cutting in the previous autumn, from the secondary roots of old plants, pieces at least 5 inches long and of the thickness of a quill, each length containing several joints for the development of buds, and preserving them through the winter in a dry place by covering them over with litter or leaves. Before planting, the land is in some districts laid in beds, about 3 feet wide, with deep intervals dug out with the spade, and the layers are set, by means of a dibble or narrow trowel, in rows, each bed containing two rows about 16 inches apart, and the layers being at a distance of 4 to 6 inches from each other. In other districts, furrows about 3 or 4 inches deep, and 1½ or 2 feet apart, are made, and in these furrows the suckers are placed at a distance of 1 foot from one another, and the furrows are then filled up with soil by means of a rake. Should the weather be dry, the plants must be watered. A watering with diluted urine after sunset greatly assists their taking root. After 3 or 4 weeks they appear above the ground. When they have grown to the length of a finger they must be well weeded and earthed up with the hoe, and this process must be repeated 4 or 6 weeks later, taking care that the roots be well covered with earth, which very much promotes their growth. The stems and leaves should not be cut off, but allowed to die down as winter approaches. Where the winter cold is very great, the roots should in the course of November be covered up with earth to the depth of 2 or 3 inches, and an additional covering of litter is also advisable as a protection from the frost. Water must on no account be allowed to stand in the furrows between the rows during the winter. In spring the covering is removed, and the plant then sends up fresh stalks and leaves as in the first year. The same attention must be paid to weeding and earthing-up during the second as the first year. A second winter and a third summer must elapse before the root is sufficiently mature to be taken up. The object of allowing the roots to remain for such a length of time in the ground seems to be to give time for the interior or woody part of the root to increase; for this part, though it is no richer in colouring matter than the outer or fleshy part of the root, yields a product of finer quality. In France, however, it is usual to gather the crop in 18 months after planting, that is, in the autumn of the second year.

In Germany the roots are sometimes even taken up at the end of the first year, and it is to the product thus obtained that the special name of *Röthe* is applied, the term *Krapp* being restricted to that which has been in the ground the usual length of time. The root is the only part of the plant generally used. The East Indian product called *Munjeet* seems, however, to consist entirely of the stalks of the madder plant. It is much inferior in quality to ordinary madder, and is comparatively poor in colouring-matter.

The time usually selected for taking up the roots is October or November. In doing so care must be taken to break and injure them as little as possible. The quantity of fresh roots obtained in France from one arpent of ground (of 48,000 square feet) varies from 4,000 to 6,000 lbs. In England an acre of ground will yield from 10 to 20 cwts., and in the south of Germany the produce of 1 morgen of land (equal to about 4,075 square yards) amounts to 50 cwts. of dry roots. In warm climates the roots, as soon, as they are taken out of the ground, are simply dried in the sun, and after having been separated from the earth, &c., are broken into pieces, and then brought to market. This kind of madder is called in the East *Alizari*, and in England *Madder-roots*. It consists of short twisted pieces, a little thicker than a quill, reddish-brown, and rather rough externally. A transverse section of one of these pieces exhibits in the centre several concentric layers of pale yellowish-red woody fibre, surrounded by a thin reddish-brown layer of cellular tissue, the original volume of which has been much reduced by drying. Madder is also imported in this state from France, Naples, and Bombay.

In France and Holland the cultivator generally dries his roots, after shaking out the earth as much as possible, partially in stoves. He then takes them to the threshing-floor, and threshes them with the flail, partly for the purpose of separating the small radicles and epidermis of the root, and partly in order to divide the latter into pieces about 7 or 8 centimètres in length. They are then sieved or winnowed, in order to remove what has been detached by threshing. The particles which are separated in this process are ground by themselves, and constitute an inferior kind of madder called *Mull*. The remainder is then handed over to the madder manufacturer, who proceeds to dry it completely in stoves heated to about 100° Fahr. by means of furnaces so constructed as to allow an occasional current of fresh air to pass through. It is afterwards taken to a large sieve with different compartments, moved by machinery. The compartment with the narrowest meshes serves to separate the portions of epidermis, earthy particles, and other refuse matter which had been left adhering to the roots after the threshing. The compartments with wider meshes are for the purpose of separating the smaller roots from the larger ones, the latter being considered the best. In France this operation is called *robage*. The roots are then subjected to the process of grinding, by means of vertical millstones, and afterwards passed through sieves of different sizes, until they are reduced to a state of fine powder. When the larger and better roots are ground by themselves, the madder is called in France *garance robée fine*, or *garance surfine*, and it is marked with the letters S F. The smaller roots yield an inferior madder, which is called *garance non robée*, or *mifine*, and is marked M F. When the different kinds of roots are not separated from one another, but all ground together, the product is called *garance petite robée, moins robée*, or *fine*, and is marked F F. By far the greater portion of the madder consumed in France consists of this quality, since it is found to be perfectly well adapted for all the purposes to which madder is usually applied. The letter O is applied to the lowest quality of madder or mull, which is obtained by grinding the epidermis and other portions of the root which are detached after the first stoving, and during the process called *robage*. The qualities C F and C F O consist of mixtures of M F and O. There is also another quality, which receives the designation S F F, and which is obtained by grinding separately the internal ligneous part of the root, previously deprived of the outer or cortical portion. This quality is employed for dyeing fine colours on wool and silk, as well as for the preparation of madder-lakes. Other marks, such as S F F F, E X S F F F, &c., are also occasionally employed by French manufacturers and dealers, to distinguish particular qualities. In Holland the product obtained by grinding together the whole roots, after the separation of the mull, is called *onber*, whilst the term *crop* is applied to the internal part of the root ground separately.

The Levant madder, usually called Turkey roots, is considered to be the finest quality imported into this country. It comes to us from Smyrna, and consists of the whole roots broken into small pieces, and packed in bales. It is ground as it is, without any attempt being made to separate the different portions of the root; and has then the appearance of a coarse, dark reddish-brown powder. It is employed chiefly for the purpose of dyeing the finer purples on calico. Next to this comes the madder of Avignon, of which two varieties are distinguished in commerce, viz. *Paluds* and *rosée*. The first, which is the finest, owes its name to the district in which it is grown, consisting of a small tract of reclaimed marsh land in the neighbourhood of Avignon. Avignon madder is considered to be the best adapted for dyeing pink. It has the appearance, as imported into this country, of a fine pale yellowish-brown or reddish-brown powder. The paler colour, as compared with that of ground *roots*, is owing to the partial separation of the external or cellular portion of the root during the process of grinding, as practised in France. The madders of Alsace, Holland, and Naples, are richer in colouring-matter than the two preceding kinds, but they yield less permanent dyes, and are therefore only employed for colours which require little treatment with soap and other purifying agents after dyeing. Of late years, indeed, the employment of *garancine*, a preparation of madder, in the place of these lower descriptions, has become very general.

All kinds of madder have a peculiar, indescribable smell, and a taste between bitter and sweet. Their colour varies extremely, being sometimes yellow, sometimes orange, red, reddish-brown, or brown. They are all more or less hygroscopic, so that even when closely packed in casks in a state of powder, they slowly attract moisture, increase in weight, and at length lose their pulverulent condition, and form a firm, coherent mass. This change takes place to a greater extent with Alsace and Dutch madders than with those of Avignon. Madder which has undergone this change is called by the French *garance grappée*. It is probable that some process of fermentation goes on at the same time, for madder that is kept in casks in a dry place, and as much out of contact with the air as possible, is found constantly to improve in quality for a certain length of time, after which it again deteriorates. Some kinds of madder, especially those of Alsace and Holland, when mixed with water and left to stand for a short time, give a thick coagulum or jelly, which does not take place to the same degree with Avignon madder. The madder of Avignon contains so much carbonate of lime as to effervesce with acids. The herbaceous parts of the plant, when given as fodder to cattle, are found to communicate a red colour to their bones, a circumstance which was first observed about a hundred years ago, and has been employed by physiologists to determine the manner and rate of growth of bone.

There exists no certain means of accurately ascertaining the intrinsic value of any sample of madder, except that of dyeing a certain quantity of mordanted calico with a weighed quantity of the sample, and comparing the depth and solidity of the colours with those produced by the same weight of another sample of known quality, and even this method may lead to uncertain results, if practised on too small a scale. The Paluds, which is the most esteemed of the Avignon madders, has a dark red hue, whereas the other kinds have naturally a yellow, reddish-yellow, or brownish-yellow colour. Nevertheless, means have been devised of communicating to the latter the desired reddish tinge, which, therefore, no longer serves as a test. A method formerly employed to ascertain the comparative value of a number of samples of madder consisted in placing a small quantity of each sample on a slate, pressing the heaps flat with some hard body, and then taking them to a cellar or other damp place. After 10 or 12 hours they were examined, and that which had acquired the deepest colour, and increased the most in volume was considered the best. This method led, however, to so many frauds on the part of the dealer, for the purpose of producing the desired effect, that it is no longer resorted to. Madder is sometimes adulterated with sand, clay, brick-dust, ochre, sawdust, bran, oak-bark, logwood and other dye-woods, sumac and quercitron bark. Some of these additions are difficult to detect. Such as contain tannin may be discovered by the usual tests, since madder contains naturally no tannin. If the material used for adulteration be of mineral nature, its presence may be discovered by incinerating a weighed quantity of the sample. If the quantity of ash which is left exceeds 10 per cent. of the material employed, adulteration may be suspected. The ash obtained by incinerating pure madder consists of the carbonates, sulphates, and phosphates of potash and soda, chloride of potassium, carbonate and phosphate of lime, phosphate of magnesia, oxide of iron and silica. If a considerable amount of any other mineral constituents is found, it is certainly due to adulteration.

There is probably no subject connected with the art of dyeing which has given rise to so much discussion as the composition of madder, and the chemical nature of the colouring matters to which it owes its valuable properties. The subject has engaged the attention of a number of chemists, whose labours, extending over a lengthened period, have thrown considerable light on it. Nevertheless, the conclusions at which they have severally arrived do not perfectly agree with one another, nor with the views entertained by the most intelligent of those practically engaged in madder dyeing. The older investigators supposed that madder contained two colouring matters, one of which was tawny, and the other red. Robiquet was the first chemist who asserted that it contained two distinct red colouring matters, both of which contributed to the production of the dyes for which madder is employed; and his views, though they were at the time of their promulgation strongly objected to by some of the most eminent French dyers and calico-printers, still offer probably the best means of explaining some of the phenomena occurring during the process of madder dyeing. The two red colouring matters discovered by Robiquet were named by him *Alizarine* and *Purpurine*, and these names they still retain. Several crystallised yellow colouring matters have been discovered by other chemists; but the only one which exists ready-formed in the madder of commerce is the *Rubiacine* of Schunck, and this substance may also be taken as the type of the whole class, the members of which possess very similar properties. Among the other organic substances obtained by different chemists from madder, two resinous colouring matters, sugar, a bitter principle, a peculiar extractive matter, pectin, a fermentative nitrogenous substance, and malic, citric, and oxalic acids, may be mentioned.

When madder is extracted with boiling water, a dark brown muddy liquid, having a taste between bitter and sweet, is obtained. On adding a small quantity of an acid to this liquid, a dark brown precipitate is produced, while the supernatant liquid becomes clear, and now appears of a bright yellow colour. The precipitate consists of alizarine, purpurine, rubiacine, the two resinous colouring matters, pectic acid, oxidised extractive matter, and a peculiar nitrogenous substance. The liquid filtered from this precipitate contains the bitter principle and the extractive matter of madder, as well as sugar and salts of potash, lime, and magnesia. No starch, gum, or tannin can be detected in the watery extract. After the madder has been completely exhausted with boiling water, it appears of a dull red colour. It still contains a quantity of colouring matter, which cannot, however, be extracted with hot water, or even alkalis, since it exists in a state of combination with lime and other bases, forming compounds which are insoluble in those menstrua. If, however, the residue be treated with boiling dilute muriatic acid, the latter dissolves a quantity of lime, magnesia, alumina, and peroxide of iron, as well as some phosphate and oxalate of lime, which may be discovered in the filtered liquid; and if the remainder, after being well washed, be treated with caustic alkali, a dark red liquid is obtained, which gives with acids a dark reddish-brown precipitate consisting of alizarine, purpurine, rubiacine, resin, and pectic acid. That portion of the madder left after treatment with hot water, acids, and alkalis, consists almost entirely of woody fibre.

A short description of some of the substances just mentioned will not be out of place here, as it may assist in rendering the process of dyeing with madder more intelligible.

The most important of these substances is *alizarine*, since it forms the basis of all the finer and more permanent dyes produced by madder. The *matière colorante rouge* of Persoz and the *madder-red* of Runge also consist essentially of alizarine, mixed with some impurities. Robiquet first obtained it in the form of a crystalline sublimate, by extracting madder with cold water, allowing the liquid to gelatinise, treating the jelly with alcohol, evaporating the alcoholic liquid to dryness, and heating the residue; and since the application of heat seemed to be an essential part of his process, it was for a long time doubted whether alizarine was contained as such in madder, and was not a product of decomposition of some other body. It was proved, however, by the experiments of Schunck that it does in reality pre-exist in the ordinary madder of commerce, though not in the fresh root when just taken out of the ground. It has the following properties:—It crystallises in long, transparent, lustrous, yellowish-red needles. These needles when heated to 212° F. lose their water of crystallisation, and become opaque. At about 420° F. alizarine begins to sublime, and if carefully heated may be almost entirely volatilised, only a little charcoal being left behind. The sublimate obtained by collecting the vapours consists of long, brilliant, transparent, orange-coloured crystals, which are pure anhydrous alizarine. If madder, or any preparation or extract of madder, be heated to the same temperature, a sublimate of alizarine is also obtained, but the crystals are then generally contaminated with drops of empyreumatic oil, produced by the decomposition of other constituents of the root. This oily matter may, according to Robiquet, be removed by washing the crystals with a little cold alcohol. Alizarine is almost insoluble in cold water. It is only slightly soluble in boiling water, and is deposited, on the solution cooling, in yellow crystalline flocks. When the water contains large quantities of acid or salts in solution, it dissolves very little alizarine, even on boiling. The colour of the solution is yellowish when it is quite free from alkalis or alkaline earths. Alizarine dissolves much more readily in alcohol and ether than in water; the solutions have a deep yellow colour. Alizarine is decomposed by chlorine, and converted into a colourless product. It is also decomposed by boiling nitric acid, the product being a colourless, crystallised acid, *phthalic acid*, the same that is formed by the action of nitric acid on naphthaline. Alizarine dissolves in concentrated sulphuric acid, yielding a yellow solution, which may be heated to the boiling point without changing colour and without any decomposition of the alizarine, which is precipitated unchanged on the addition of water. Alizarine dissolves in caustic alkalis with a splendid purple or violet colour, which remains unchanged on exposure of the solutions to the air. The ammoniacal solution, however, loses its ammonia entirely on being left to stand in an open vessel, and deposits its alizarine in the form of shining prismatic crystals, or of a crystalline crust. The alkaline solutions give with solutions of lime and baryta salts precipitates of a beautiful purple colour, with alumina salts a red, with iron salts a purple precipitate, and with most of the salts of metallic oxides precipitates of various shades of purple. The affinity of alizarine for alumina is so great, that if the compound of the two bodies be treated with boiling caustic potash-lye, it merely changes its colour from red to purple without being decomposed. Alizarine is not more soluble in boiling alum-liquor than in boiling water. The chemical formula of anhydrous alizarine is, according to the researches of Messrs. Graebe and Liebermann, $C^{14}H^{4}O^{4}$ ($\mathbf{C^{14}H^{8}O^{4}}$).

If alizarine in a finely divided or, what is still better, in a freshly precipitated state, be suspended in distilled water, and a piece of calico printed with alumina and iron mordants of different strengths be plunged into it, the latter, on gradually heating the bath, become dyed. The process is necessarily a slow one, because alizarine is only slightly soluble in boiling water, and as the mordants can only combine with that portion actually in solution, a constant ebullition of the liquid must be kept up, in order to cause fresh portions of colouring matter to dissolve in the place of that portion taken up by the mordants. A very small proportional quantity of alizarine is required in order to dye very dark colours, but it is absolutely necessary that the bath should contain no trace of either acid or base, since the former would combine with the mordants, and the latter with the alizarine. When the process is complete the alumina mordant will be found to have acquired various shades of red, while the iron mordant will appear either black or of different shades of purple, according to the strength of the mordant employed. These colours are as brilliant and as permanent as those obtained from madder by means of a long and complicated process. Nevertheless, the red is generally found to have more of a purplish hue, and the black to be less intense than when madder or its preparations are employed. On the other hand, if one of the finer madder colours which are produced on calico, such as pink or lilac, be examined, the colours are found to contain, in combination with the mordants, almost pure alizarine. Hence it may be inferred, that alizarine alone is required for the production of these colours, and that the simple combination of this colouring matter with the mordants is the principal end which is to be attained by the dyer in producing them.

Alizarine has been obtained artificially by Messrs. Graebe and Liebermann, as a derivative of anthracene or paranaphthaline, which is one of the products obtained in the distillation of coal-tar. Artificial alizarine is now extensively manufactured and used for a substitute for madder. By the action of bromine upon alizarine, Mr. Perkin has recently obtained a derivative called *bromalizarine*, which may also be used in dyeing. For the manufacture of artificial alizarine, see ALIZARINE; ANTHRACENE.

Purpurine, the other red colouring matter of madder, with which the *matière colorante rose* of Gaultier de Claubry and Persoz, and the *madder-purple* of Runge, are substantially identical, can hardly be distinguished by its appearance from alizarine, which it also resembles in most of its properties. It crystallises in small orange-coloured or red needles. When carefully heated it is almost entirely volatilised, yielding a sublimate of shining orange-coloured scales and needles. It is slightly soluble in boiling water, giving a pink solution. It is more soluble in alcohol than in water, the solution having a deep yellow colour. It dissolves in concentrated sulphuric acid, and is not decomposed on heating the solution, even to the boiling point. It is decomposed by boiling nitric acid, and yields, like alizarine, phthalic acid. It is distinguished from alizarine, by its solubility in alum-liquor. When treated with a boiling solution of alum in water, it dissolves entirely, yielding a peculiar opalescent solution, which appears of a bright pink colour by transmitted light, and yellowish by reflected light. The solution deposits nothing on cooling, but on adding to it an excess of muriatic or sulphuric acid, it becomes colourless, and the purpurine falls down in yellow flocks. On this property depends the method of separating it from alizarine. The compounds of purpurine with bases are mostly purple. It dissolves in alkalis with a bright purplish-red or cherry-red colour. If the solution in caustic potash or soda be exposed to the air, its colour changes gradually to reddish-yellow, and the purpurine contained in it is decomposed, a characteristic which also serves to distinguish purpurine from alizarine, the alkaline solutions of which are not changed by the action of oxygen. The composition of purpurine approaches very near to that of alizarine, but its chemical formula is unknown. It communicates to calico, which has been printed with various mordants, colours similar to those imparted by alizarine, but the red is more fiery, and the black more intense than when alizarine is employed. On the other hand, the purple dyed by means of purpurine has a disagreeable reddish tinge, and presents an unpleasant contrast with the beautiful purple from alizarine. The name of this colouring matter is therefore very inappropriate, and is calculated to mislead. The colours dyed with purpurine are less stable than those dyed with alizarine, they are less able to resist the action of soap and other agents than the latter. Hence, very little purpurine is found in combination with the mordants, in such madder colours as have undergone a course of treatment with alkalis and acids, after having been dyed; indeed, the principal object of this treatment appears to be the removal of this and other substances, so as to leave compounds of alizarine only on the fabric. Purpurine seems to abound more in the lower, stronger qualities of madder than in the finer. To this cause, Robiquet chiefly ascribed the superiority of the latter in dyeing fast colours, and no better way of accounting for it has hitherto been suggested. Purpurine forms the basis of the red pigment called madder-lake.

Rubiacine is the name which has been applied to a yellow crystallised colouring matter contained in madder. It coincides in most of its properties with the *madder-orange* of Runge. It crystallises in greenish-yellow lustrous scales and needles. When heated it is entirely volatilised, yielding a crystalline sublimate. It is only slightly soluble in boiling water, but more soluble in boiling alcohol, from which it crystallises on cooling. It dissolves in concentrated sulphuric acid, and is not decomposed on boiling the solution. It also dissolves in boiling nitric acid without being decomposed. It dissolves in caustic alkalis with a purple colour. Its compounds with earths and metallic oxides are mostly red. When treated with a boiling solution of pernitrate or perchloride of iron it dissolves entirely, yielding a brownish-red solution, which deposits nothing on cooling, but gives, on the addition of an excess of muriatic acid, a yellow flocculent precipitate, consisting of a peculiar acid, called *rubiacic acid*.

Two amorphous resinous colouring matters, forming brownish-red compounds with bases, have also been obtained from madder. Both are very little soluble in boiling water. One of them is a dark brown, brittle, resin-like substance, very easily soluble in alcohol, which melts at a temperature a little above 212° F. The other is a reddish-brown powder, less soluble in alcohol than the preceding. These two colouring matters, together with rubiacine, constitute probably the *tawny* or *dun colouring matter* of the older chemists. They do not contribute to the intensity of the colours dyed with madder, and exert a very prejudicial effect on the beauty of the dyes. If printed calico be dyed with a mixture of alizarine, and any one of these three colouring matters, the colours are found to be both weaker and less beautiful than when alizarine is employed alone. The red acquires an orange tinge, and the purple a reddish hue, whilst the black is less intense, and the parts of the calico which should remain white are found to have a yellowish colour. Hence it is of importance to the dyer that their effect should be counteracted as much as possible, by preventing them either from dissolving in the dye-bath or from attaching themselves to the fabric.

The other constituents of madder possess no interest in themselves, but may become of importance in consequence of the effects which they produce during the process of dyeing. The pectine, in the state in which it exists in the root, is probably an indifferent substance, but in consequence of the ease and rapidity with which it passes into pectic acid, it may in dyeing act very prejudicially by combining with the mordants and preventing them taking up colouring matter. The extractive matter of madder, when in an unaltered state, produces no injurious effects directly; but by the action of oxygen, especially at an elevated temperature, it acquires a brown colour and then contributes, together with the rubiacine and the resinous colouring matter, in deteriorating the colours and sullying the white parts of the fabric. The extractive matter, when in a state of purity, has the appearance of a yellow syrup like honey, which is easily soluble in water and alcohol. When pure it is not precipitated from its watery solution by an earthy or metallic salt, but if the solution be evaporated in contact with the air, it gradually becomes brown, and then gives an abundant brown precipitate with sugar of lead. When its watery solution is mixed with muriatic or sulphuric acid and boiled, it becomes green and deposits a dark green powder. Hence this extractive matter has, for the sake of distinction, been called *Chlorogenine*, and *Rubichloric Acid*. The bitter principle of madder will be referred to presently. The *Xanthine* of Kuhlmann, and the *madder-yellow* of Runge are mixtures of the extractive matter and the bitter principle. The sugar contained in madder is probably grape-sugar. It has not hitherto been obtained in a crystallised state, but it yields by fermentation alcohol and carbonic acid, like ordinary sugar. The woody fibre which is left after madder has been treated with various solvents until nothing more is extracted, always retain a slight reddish or brownish tinge from the presence of some colouring matter which cannot be completely removed, and seems to adhere to it in the same way as it does to the cotton fibre of unmordanted calico.

There is a question connected with the chemical history of madder which must not be passed over in silence, since it is one which possesses great interest, and may at some future time become of great importance, viz. the question as to the state in which the colouring matters originally exist in the root. It has long been known, that when ground madder is kept tightly packed in casks for some time, it constantly improves in quality for several years, after which it again deteriorates; and it was always supposed that this effect was due to some process of slow fermentation going on in the interior of the mass, an opinion which seemed to be justified by the evident increase in weight and volume, and the agglomeration of the particles which took place at the same time. Nevertheless, the earlier chemical examinations of madder threw no light whatever on this part of the subject, since the red colouring matters were found to be very stable compounds, not easily decomposed except by the action of very potent agents, so that when once formed it seemed improbable that they would be at at all affected by any mere process of fermentation. Hence some chemists were led to the conclusion that the improvement which takes place in the quality of madder on keeping is caused by an actual formation of fresh colouring matter. A very simple experiment may indeed suffice to prove that the whole of the colouring matter does not exist ready formed, even in the article as used by the dyer. If ordinary madder be extracted with cold water, the extract after being filtered has generally an acid reaction, and cannot contain any of the colouring matters, since these are almost insoluble in cold water, especially when there is any acid present. Nevertheless the extract when gradually heated is found capable of dyeing in the same way as madder itself. If the extract be made tolerably strong, it possesses a deep yellow colour and a very bitter taste; but if it be allowed to stand in a warm place for a few hours, it gelatinises, and the insoluble jelly which is formed is found to possess the whole of the tinctorial power of the liquid, which has also lost its yellow colour and bitter taste. Hence, it may be inferred that the substance which imparts to the extract its bitter taste and yellow colour is capable also of giving rise to the formation of a certain quantity of colouring matter.

In 1837 a memoir was published by Decaisne, containing the results of an anatomical and physiological examination of the madder plant, results which were considered so important that a prize was awarded to the author by the Royal Academy of Sciences at Brussels. This investigation led the author to the conclusion, that the cells of the living plant contain no ready-formed red colouring matter, but are filled with a transparent yellow juice, which, on exposure to the atmosphere, becomes reddish and opaque in consequence of the formation of red colouring-matter. Hence he inferred that the insoluble red colouring-matter was simply a product of oxidation of the soluble yellow one, and that, consequently, the more complete the exposure of the triturated root to the atmosphere, the greater would be its tinctorial power; and he even went so far as to assert that all the proximate principles obtained from the root were derived ultimately from one single substance contained in the whole plant. That the fresh roots, before being dried, do indeed contain no colouring-matter capable of imparting to mordants colours of the usual appearance and intensity, may be proved by the following experiment:—If the roots, as soon as they are taken out of the ground, are cut into small pieces as quickly as possible, and then extracted with boiling spirits of wine, a yellow extract is obtained, which, after being filtered and evaporated, leaves a brownish-yellow residue. Now this residue, on being redissolved in water, is found incapable of imparting to mordants any but the slightest shades of colour; and, on the other hand, the portion of the root left after extraction with spirits of wine, on being subjected to the same test as the extract, is found to possess as little tinctorial power as the latter. If, however, the roots, instead of being treated with spirits of wine, are macerated in water, the liquor, on being gradually heated, dyes the usual colour as well as ordinary madder. Hence it may be inferred that by means of alcohol the colour-producing body of the root may be separated from the agent which, under ordinary circumstances, is destined to effect its transformation into colouring-matter, the one being soluble and the other insoluble in that menstruum. It was by this and other similar facts that Schunck was led to an examination of this part of the subject. He infers from his experiments that the colour-producing body of maddder is identical with its so-called bitter principle, to which he has given the name of *Rubian*. This body, when pure, has the following properties:—It is an amorphous, shining, brittle substance like gum, dark brown and opaque in mass, but yellow and transparent in thin layers. Its solutions are of a deep-yellow colour, and have an intensely-bitter taste. It is easily soluble in water and alcohol. The watery solution turns of a blood-red colour on the addition of caustic and carbonated alkalis, and gives dark-red precipitate with lime and baryta-water. The solution gives a copious light-red precipitate with basic acetate of lead, but yields no precipitate with any other metallic salt. On trying to dye with rubian in the usual manner, the mordants assume only the faintest shades of colour. If, however, the watery solution be mixed with sulphuric or muriatic acid and boiled, it gradually deposits a quantity of insoluble yellow flocks, which, after being separated by filtration and well washed, are found to dye the same colour as those obtained by means of madder. In fact, these flocks contain alizarine, to which they owe their tinctorial power, but they also contain a crystallised yellow colouring-matter, similar to, but not identical with, rubiacine, as well as two resinous colouring-matters, which Schunck has named *Verantine* and *Rubiretine*, and which are probably identical with the resinous colouring-matters before referred to as being obtained from ordinary madder. The liquid filtered from the flocks contains an uncrystallisable sugar, similar to that which is obtained from the madder itself. Rubian is not decomposed by ordinary ferments, such as yeast and decomposing-casein; but by extracting madder with cold water, and adding alcohol to the extract, a substance is precipitated in pale-red flocks, which possesses in an eminent degree the power of effecting the decomposition of rubian. If a watery solution of the latter be mixed with some of the flocculent precipitate (after having been collected on a filter, and washed with alcohol), and then left to stand in a warm place for some hours, the mixture is converted into a light-brown jelly, which is so thick that the vessel may be reversed without its falling out. This jelly, when agitated with cold water, communicates to the latter very little colour or taste, proving that the rubian has undergone complete decomposition by the action of the flocculent substance or ferment added to its solution. The cold water, however, extracts from the gelatinous mass a quantity of sugar, while the portion left undissolved contains alizarine, verantine, rubiretine, and a crystalline yellow colouring-matter, besides a portion of undecomposed ferment. Rubian, therefore, by the action of strong mineral-acids and of the peculiar ferment of madder, is decomposed, yielding sugar and a variety of colouring-matters, the principal of which is alizarine. It appears, therefore, that these colouring-matters are not originally contained as such in the root, but are formed by the decomposition of one parent substance, which alone is produced by the vital energies of the plant. In addition to this substance, the plant also contains another, which possesses the property of rapidly effecting the decomposition of the first. The two are, however, during the living state of the plant, prevented from acting on one another, either in consequence of their being contained in different cells, or because the vital energies of the plant resist the process of decomposition. During the drying and grinding of the root the decomposition of the colour-producing body commences and continues slowly during the period that the powder is kept before being used. It is finally completed during the process of dyeing itself, and hence no trace of colour-producing substance can be detected, either in the liquor or the residual madder, after the operation of dyeing is concluded. The presence of oxygen does not seem to be essential during this process of decomposition, as Decaisne supposed. Nevertheless, according to Schunck, rubian does in reality suffer a partial oxidation when its watery solution, mixed with some alkali or alkaline earth, is exposed to the action of the atmosphere, giving rise to a peculiar acid, called by him *rubianic acid.* When rubian is heated at a temperature considerably exceeding 212° Fahr., it is converted without much change of appearance into a substance which yields by decomposition resinous colouring-matters in the place of alizarine. The great excess of these colouring-matters contained in the madder of commerce arises, therefore, most probably from the high temperature employed in drying the root.

Employment of Madder in Dyeing.—After the account which has just been given of the composition of madder, it may easily be conceived that the chemical and physical phenomena which occur during the various processes of madder-dyeing, are of a rather complicated nature, and that many of these phenomena have not yet received a perfectly satisfactory explanation. Nevertheless, the present state of our knowledge on this subject may enable us to give a consistent explanation of the facts presented to us by the experience of the dyer, and even to indicate what direction our labours must take if we wish to improve this branch of the arts.

In order to produce perfectly-fast colours in madder-dyeing, it is necessary that the madder should contain a large proportion of carbonate of lime, and if the madder is naturally deficient in that salt, the deficiency may be supplied either by using calcareous water in dyeing, or by adding a quantity of ground chalk. If madder be treated with dilute sulphuric or muriatic acid, so as to dissolve all the lime contained in it, and then washed with cold water until the excess of acid is removed, its tinctorial power will be found to be very much diminished, but may be entirely restored, and even increased, by the addition of a proper quantity of lime-water or chalk. Hence, too, Avignon madder, which is grown in a highly-calcareous soil, and contains so much carbonate of lime as to effervesce with acids, affords the most permanent colours; whilst Alsace madder requires the addition of carbonate of lime in order to produce the same effect. This fact was first pointed out by Hausmann, who, after having produced very fine reds at Rouen, encountered the greatest obstacles in dyeing the same reds at Logelbach, near Colmar, where he went to live. Numerous trials, undertaken with the view of obtaining the same success in his new establishment, proved that the cause of his favourable results at Rouen existed in the water, which contained carbonate of lime in solution, whilst the water of Logelbach was nearly pure. He then tried a factitious calcareous water by adding chalk to his dye-bath. Having obtained the most satisfactory results, he was not long in producing here as beautiful and as solid reds as he had done at Rouen. This simple fact led to the production of a series of lengthy Memoirs on the part of some of the French chemists and calico-printers, which fully confirmed the results of Hausmann, without, however, leading to a satisfactory explanation of them. The experiments of Robiquet prove that in dyeing with pure alizarine the least addition of lime is rather injurious than otherwise, as it merely weakens the colours without adding to their durability. Hence the beneficial effect of lime can only be accounted for by some action which it exerts on other constituents of the root. Bartholdi imagined that this action consisted simply in the decomposition of the sulphate of magnesia, which he found to be contained in ordinary madder. It was asserted by others that the carbonate of lime served to neutralise some free acid, supposed by Kuhlmann to be malic acid, which was present in some madders, and which not only to a great degree prevented the colouring-matters from dissolving in the dye-bath, but also combined with the mordants to the exclusion of the latter. Though later researches have failed to detect the existence of malic acid in madder, still it is certain that all watery extracts of madder contain pectic acid, which probably exists in the root originally as pectine; and that this acid, when in a free state, acts most injuriously in dyeing with alizarine, but ceases to do so as soon as it is combined with lime. Nevertheless, it seems that madder which is naturally deficient in lime, cannot be made to replace entirely such madder as has been grown in a calcareous soil, however great an excess of chalk be used in dyeing. Hence Robiquet was led to the conclusion that the inferior kinds of madder, which are also the most deficient in lime, contain more purpurine and less alizarine than the superior kinds, and that the carbonate of lime serves partly to combine with the purpurine, and prevent it from uniting with the mordants, and thus producing less permanent dyes. The experiments of Schunck have proved that not only pectic acid, but also rubiacine and the resinous colouring-matters of madder, act detrimentally in dyeing with pure alizarine, by deteriorating the colours and sullying the white parts of the fabric, and that these effects are entirely neutralised by the addition of a little lime-water to the dye-bath. If in dyeing with madder the whole of the colouring-matters were in a free state, the resinous and yellow colouring-matters would, according to Schunck, unite with the mordants, to the exclusion of the alizarine, yielding colours of little permanency and of a disagreeable hue; but on adding lime, they combine with it, and the alizarine, being less electro-negative, then attaches itself to the mordants or weaker bases. A great excess of lime would of course have an injurious effect by combining also with the alizarine, and preventing it from exerting its tinctorial power. In practice a little less lime is added than is sufficient to take up the whole of the impurities with which the alizarine is associated, thus allowing a portion of the former to go to the mordants, to be subsequently removed by treatment with soap and other detergents. Lastly, it has been asserted by Köchlin and Persoz that when lime is used in dyeing with madder the colours produced are not simply compounds of colouring-matter with mordants, but contain also in chemical combination a certain quantity of lime, which adds very much to their stability. It is probable that all these causes contribute in producing the effect. The carbonates of magnesia and zinc, acetate and neutral phosphate of lime, and the protoxides of lead, zinc and manganese, act in a similar manner to carbonate of lime in madder-dyeing, but are less efficient.

Dambourney and Beckman have asserted that it is more advantageous to employ the fresh root of madder than that which has been submitted to desiccation, especially by means of stoves. But in its state of freshness its volume becomes troublesome in the dye-bath, and uniform observation seems to prove that it ameliorates by age up to a certain point. Besides, it must be rendered susceptible of keeping and carrying easily.

In dyeing printed calicoes with madder, the general course of proceeding is as follows:—The madder having been mixed in the dye-vessel with the proper quantity of water, and, if necessary, with chalk, the liquid is heated slowly by means of fire or steam, and the fabric is introduced and kept constantly moving until the dyeing is finished. (See Calico-Printing.) The temperature should be kept low at first, and should be gradually raised, without allowing it to fall, until it reaches the boiling-point; and the boiling may, if necessary, be continued for a short time. The chief object of the gradual heating seems to be to allow the ferment to exert its full power on the rubian or colour-producing body; for this process, like all processes of fermentation, is most active at a temperature of about 100° Fahr., and is arrested at 212° Fahr. In dyeing quickly less permanent colours are also produced, in consequence, probably, of the colouring-matters combining with the more superficial portions of the mordants, and not penetrating sufficiently into the interior of the vegetable fibre. The fastest colours are produced by dyeing at a moderate temperature, and not allowing the liquid to boil. By boiling the madder becomes more thoroughly exhausted, and a greater depth of colour is attained, but the latter resists less perfectly the action of soap and other agents, than the same shade dyed at a lower temperature. The time occupied in dyeing varies according to the nature and intensity of the colours to be produced; but there is little advantage in allowing it in any case to exceed 3 hours, since the gain in colour acquired is more than counterbalanced by the loss of time and increased expenditure of fuel caused by a long-continued ebullition. In dyeing ordinary madder colours, such as red, black, chocolate, and common purple, which do not require much treatment after dyeing, in order to give them the desired tone and intensity, strong but inferior qualities of madder may be used with advantage; and various other dye-stuffs, such as peach-wood, quercitron-bark, sumac, &c., are often added to the madder, in order to vary the shade and depth of colour. But for the finer colours, such as pink and fine purple, which after dyeing must be subjected to a long course of treatment with soap and acids before they assume the requisite beauty and delicacy of hue, it is necessary to employ the finest qualities of madder; for if dyed with inferior qualities they would resist only imperfectly the requisite after-treatment, and great care must be observed in regulating the temperature during dyeing. The addition of other dye-stuffs, in their case, would be not only useless, but positively injurious. The use of different kinds and qualities of madder in conjunction is often found to be attended with benefit, arising probably from the circumstance of one kind supplying some material or other, such as ferment or carbonate of lime, in which the other is deficient.

The chemical processes which take place during the operation of dyeing may be shortly described as follow:—In the first place, the water of the dye-bath extracts the more soluble constituents of the madder, such as the sugar, extractive matter, and bitter principle. The latter substance is decomposed by the ferment, and the colouring-matter thereby formed is added to that which already exists in the root. As the temperature rises the less soluble constituents, such as the alizarine, purpurine, rubiacine, the resinous colouring-matters, the pectine and pectic acid, begin to dissolve, and as they dissolve they combine partly with the mordants of the fabric, partly with the lime and other bases contained in the root or added to the dye-bath, and thus permit the liquid to take up fresh quantities from the madder. If the quantity of madder was exactly proportioned to the quantity of fabric to be dyed, then it becomes, in this way, gradually exhausted of all available colouring-matter. The extractive matter at the same time acquires a brown colour by the combined action of the heat and oxygen, and covers the whole surface of the fabric with a uniform brown tinge. When the dyeing is concluded the liquor appears muddy and of a pale dirty-red colour. It still contains a quantity of colouring-matter in a state of combination with lime and other bases from the madder, or with portions of the mordant mechanically detached from the fabric. The residual matter at the bottom of the liquor also contains a quantity of colouring-matter in a similar state of combination. By mixing the residue and the liquor with sulphuric or muriatic acid, boiling, and then washing with water, the various bases are removed, and the colouring-matter is thus made available for dyeing. Occasionally, when a very great depth of colour is required, it is found advisable to let the goods pass through a second dyeing operation, instead of obtaining the requisite shade at once.

After the calico has been removed from the dye-bath and washed in water, it presents a very unsightly appearance. The alumina-mordant has acquired a dirty brownish-red colour, and the iron-mordant a black- or brownish-purple, according to its strength, whilst the white portions are reddish-brown. In the case of ordinary colours the fabric is now passed through a mixture of boiling bran-and-water, or through a weak solution of chloride of lime, or it is exposed for some time on the grass to the action of air and light, or it is subjected to several of these processes in succession, by which means the impurities adhering to the mordants or the fibre are, in a great measure, either removed or destroyed, the white portions recovering their purity, and the red, black, purple, and chocolate, appearing afterwards sufficiently bright for ordinary purposes. That the colours, however, even after being thus treated, still contain in combination with the mordants other substances in addition to the red colouring-matters, may be proved by a very simple experiment. If a few yards of some calico, which has been treated as just described, be immersed in dilute muriatic acid in the cold, the mordants are removed, and the colours are destroyed; orange-coloured stains being left on the places where they were before fixed. After washing the calico with cold water, the orange-coloured matter may be dissolved in alkali, and the calico left entirely white. The solution, which is brownish-red, gives, with an excess of acid, a reddish-brown flocculent precipitate. This precipitate, after being collected on a filter and well washed with water, is found to be only partially soluble in boiling alcohol, a brown substance, consisting partly of pectic acid, being left undissolved. The yellow alcoholic solution leaves, on spontaneous evaporation, a brown crystalline residue, which is found on examination to contain alizarine, purpurine, a little rubiacine, or some similar compound, and a brown amorphous substance. The removal of these various impurities, associated with the alizarine, seems to be a principal object of the treatment to which madder-colours are subjected, when it is desired to give them the highest degree of brilliancy of which they are susceptible. This course of treatment, as applied to printed calicoes, may be shortly described as follows:—The goods, after being very fully dyed, generally with the addition of chalk, and then washed, are passed for some time through a solution of soap, which is heated to a moderate temperature. By this means a great deal of colour is removed, as may be seen by the red tinge of the soap-liquor, and the purity of the white portions is almost entirely restored. During this process the brown and yellow colouring-matters are probably removed by double decomposition, the alkali of the soap combining with and dissolving them, while the fat acid takes their place on the fabric. After being washed the goods are passed through a weak solution of acid, mostly sulphuric or oxalic acid, or an acid tin-salt, which causes the colours to assume an orange tinge. The point at which the action of this acid-liquid is to be arrested can only be ascertained by practice. The next step in the process is, after washing the goods, to treat them again with soap-liquor, which is gradually raised to the boiling-point, and they are lastly subjected to the action of soap-liquor in a close vessel under pressure. By exposing the goods on the grass for some time after the first soaping, the use of acid may be obviated, but the process then becomes much more tedious. In this way are produced those beautiful pinks and lilacs which, for delicacy of hue, combined with great permanence, are not surpassed by any dyed colours known in the arts. Whether the fat acid of the soap employed forms an essential constituent of these colours is not certainly known, but it is probable that it contributes to their beauty and durability. It is certain, however, that they always contain fat acid. If a piece of calico which has gone through the processes just described be treated with muriatic acid, the colour is destroyed, and a yellow stain is left in its place. This yellow stain disappears on treating the calico, after washing with water, with alkali, yielding a solution of a beautiful purple colour. This solution gives again with an excess of acid a yellow, flocculent precipitate, which, after filtration, dissolves almost entirely in boiling alcohol, and the solution on evaporation affords needle-shaped crystals of pure alizarine, mixed with white masses of fat acid. The latter, therefore, seems to occupy the place taken up by the impurities before the treatment with soap. This experiment serves also to prove that it is alizarine which forms the basis of the more permanent colours afforded by madder, though, on the other hand, as in dyeing the finer madder colours, it cannot be denied that the colouring-matters which are removed by the treatment with soap and acids contribute to the effect produced in dyeing ordinary madder colours.

The same result is attained in dyeing Turkey red, but the process employed is somewhat different and much more complicated. See TURKEY RED.

The attempts which have been made at various times to obtain an extract of madder, capable of being applied in making so-called steam-colours for calico and other fabrics, have not been completely successful. A very beautiful pink has been produced by Gastard and Girardin, in France, by printing on calico, previously prepared with some mordant, an ammoniacal solution of an extract of madder called *colorine*, but it is not much superior, either as regards its hue or its degree of permanency, to what can be obtained by easier processes from dye-woods and other materials.

Madder is not so much employed in woollen dyeing, especially in this country, as in cotton dyeing and printing. Only ordinary woollen goods are dyed red with madder, since the colour is not so bright as that obtained from cochineal or lac, though it is more permanent and cheaper. A mixture of alum and tartar is employed as a mordant. The addition of a little muriate of tin in dyeing imparts to the colour a more scarlet tinge. The bath of madder, at the rate of from 8 or 16 ounces to the pound of cloth, is heated to such a degree as to be just bearable by the hand, and the goods are then dyed by the wince, without heating the bath more until the colouring matter is fixed. Vitalis prescribes as a mordant, $\frac{1}{4}$th of alum and $\frac{1}{16}$th of tartar; and for dyeing $\frac{1}{3}$rd of madder, with the addition of $\frac{1}{24}$th of solution of tin, diluted with its weight of water. He raises the temperature in the space of one hour to 200°, and afterwards he boils for three or four minutes, a circumstance which is believed to contribute to the fixation of the colour. The bath, after dyeing, appears to contain much yellow colouring-matter. Sometimes a little archil is added to the madder, in order to give the dye a pink tinge; but the effect is not lasting. By passing the goods after dyeing through weak alkali, the colour acquires a blueish tinge. By adding other dye-stuffs, such as fustic, peachwood, and logwood, to the madder in dyeing, various shades of brown, drab, &c., are obtained. Madder is also used in conjunction with woad and indigo in dyeing woollen goods blue, in order to impart to the colour a reddish tinge. See INDIGO.

Silk is seldom dyed with madder, because cochineal affords brighter tints.

Preparations of Madder.—The numerous analytical investigations of madder, undertaken chiefly in consequence of the Société Industrielle de Mulhouse having offered in the year 1826 a premium for a means of discovering the real quantity of colouring-matter in the root, and of determining the comparative value of different samples of madder, led to many attempts on the part of chemists to improve the quality of this dye-stuff by means of chemical agents, and thus render it more fit for the purposes to which it is applied. Robiquet and Persoz were the first to point out the advantages which result from submitting madder, previous to its being used, to the action of strong acids. They showed that, by acting on madder with strong sulphuric acid, and then carefully washing out the acid with water, a product was obtained which not only possessed a greater tinctorial power than the original material, but also dyed much brighter colours. This important discovery, which was not, like so many others, arrived at by chance, but was purely the result of scientific investigation, did not at first receive, on the part of practical men, the appreciation which it deserved. The product obtained by the action of sulphuric acid on madder, which in the first instance was called *charbon sulfurique*, afterwards *garancine*, was first manufactured on a large scale by MM. Lagier and Thomas, of Avignon, but so great were the prejudices entertained by dyers and calico-printers against its use at the commencement, that years elapsed before they could be overcome; indeed they were partly justified by the imperfect nature of the product itself. The persevering efforts to improve the method of manufacture, and adapt it to the wants of the consumer were at last attended with success, so that at the present day garancine has come to be used to as great an extent as madder, and large quantities of it are now manufactured in France and other countries.

It was supposed by Robiquet, that by the action of sulphuric acid on madder the saccharine, mucilaginous, and extractive matters of the root were destroyed, and thus hindered from producing any injurious effects in dyeing, and that the woody fibre was at the same time charred, so as to prevent it from attracting and binding any of the colouring-matter. This explanation is not entirely correct, since it is not necessary to carry the action so far as actually to carbonise any of the constituents of the root, and it is also doubtful whether the woody fibre ever attracts the useful colouring-matters in any considerable degree. The account above given of the chemical constitution of madder, may easily lead us to the conclusion, that, during the action of the acid, the following processes take place:—1. The bitter principle or colour-producing body of the root is decomposed, yielding, among other products, a quantity of alizarine which did not previously exist. 2. The red colouring-matters are rendered by the acid insoluble in water, and thus it becomes possible to wash out the extractive matter, sugar, &c., without the madder losing any of its tinctorial power. 3. The lime, magnesia, and other bases which are combined in the root with colouring matter, or would combine with it during the dyeing process, are removed by the acid, and thus prevented from exerting any injurious action. The subsequent addition of a suitable quantity of lime, soda, or other base, serves to neutralise the effect of the excessive amount of pectic acid and resinous colouring matters, which were set free by the action of the mineral acid.

The method of manufacturing garancine, as practised at the present day, may be shortly described as follows:—The ground madder is mixed with water, and the mixture is left to stand for some hours. During this time it is probable that the rubian is decomposed by the ferment of the root, otherwise a great loss would be experienced. More water is now added, in order to remove all the soluble matters, and is then run off. The liquid contains sugar, and is employed on the Continent for the preparation of a kind of spirit, which on account of its peculiar smell and flavour cannot be consumed as a beverage, but is used in the arts for the preparation of varnishes and other purposes. A sufficient quantity of alcoholic spirit is thus obtained to pay for the whole cost of the process. The residue left after washing the madder may be employed for dyeing without any further preparation, and is then called *fleur de garance.* In order to convert it into garancine, it is mixed with sulphuric acid, and the mixture is heated and left to itself for some time. Water is then added in successive portions until the excess of acid is removed. The pectic acid of the root always retains a portion of the sulphuric acid in chemical combination; and the compound being but little soluble in water would require for its removal a very long washing. The addition of a small quantity of carbonate of soda, by neutralising this double acid, serves to abridge the time of washing very considerably. The residue is then filtered on strainers, pressed, dried, and lastly ground into a fine powder. This powder has a dark reddish-brown colour, and a peculiar odour, different from that of madder, but no taste. It communicates hardly any colour to cold water. Dyeing with garancine is attended with the following advantages:—1. The whole tinctorial power of the madder is exerted at once, and garancine is therefore capable of dyeing more than the material from which it is made. 2. The colours produced by its means are much brighter than those dyed with madder, and the parts of the fabric destined to remain white attract hardly any colour, so that very little treatment is required after dyeing. 3. Much less attention is required in regard to the temperature of the dye-bath and its gradual elevation than with madder, and a continued ebullition produces no injurious effects, but only serves to exhaust the material of all its colouring-matter. On the other hand, garancine colours are not so fast as madder colours, they do not resist so well the action of soap and acids, and hence garancine cannot be employed for the production of the more permanent colours, such as pink and fine purple. By the use of a product which was patented by Pincoffs and Schunck several years ago, and which is obtained by exposing garancine to the action of steam of high pressure it is indeed possible to dye as beautiful and as permanent a purple as with madder, and its use is attended by a considerable saving of time as well as of dyeing material and soap, but it is not so well adapted for dyeing pink. As yet therefore we have not succeeded in obtaining a preparation which shall serve as a perfect substitute for madder, and the latter consequently continues to be employed for some purposes.

The residue left after dyeing with madder as well as the dyeing liquor still contain some colouring-matter in a state of combination, as mentioned above. By acting on it with sulphuric acid it affords a product similar to garancine, which is called *garanceux.* This product is, however, adapted only for dyeing red and black, as it does not afford a good purple. (See Calico-Printing.) Numerous other methods of treating madder for the use of the dyer have been invented and patented of late years, but they are not sufficiently important to merit description within the limits of the present article.—E. S.

The following notes of a journey to the madder-growing districts of France, (October 1866), by James Higgin, who contributed the important article on Calico-Printing, will be found to have considerable interest:—'The part of the Comtat d'Avignon where madder is grown is a flat basin, bounded on the north and north-east by mountains of limestone, spurs of which, gradually declining in height, run east and west. This basin is plentifully watered: in the north by several streams which rise in the mountains towards the north-east, and run, in a south-westerly direction, into the Rhône; along the south-west boundary runs the fine river Durance, which, like all the other streams, joins the Rhône—in this case below the town of Avignon; between the Durance and the mountains, and about the centre of the Comtat rises the celebrated fountain of Vaucluse, or the river Sorgue. This remarkable river rises as a spring, in an amphitheatre of perpendicular rocks, about eighteen miles north-east of Avignon. A prodigious volume of water issues from a deep pool at the foot of a high precipice, and in the course of two hundred or three hundred yards the stream is augmented by numerous lateral springs; so that, at the distance of a quarter of a mile from the source, the fountain has become a considerable river, running at the rate of seven or eight miles an hour. After running a mile or two the stream divides into two main branches, which, lower down, subdivide; the one into four branches, the other into three, or seven streams in all, each of considerable volume. These seven streams permeate the central and southerly portions of the basin above described; and it is to these waters that I unhesitatingly ascribe the wonderful fertility of the district of which Avignon is the capital. The Sorgue waters are again subdivided, artificially, in a great variety of ways. Small streams run along the roadside and across the fields in every conceivable manner; the volume of water being so great and flowing so rapidly, that the agriculturist can divert it, dam it up, and irrigate his fields just as he wants, in the same manner as the people of the 'Garden of Valencia,' in Spain, apply the waters flowing through the old Moorish aqueducts, and produce thereby, with the aid of a southern sun, a fertility perhaps without parallel anywhere.

'The result of this abundance of water is that the soil is kept naturally *moist*; not, be it understood, *wet*, but to such a degree of moisture as naturally occurs when water is found anywhere from two to four yards below the surface. In some parts of the basin are patches of land, where formerly were small lakes, which have dried up. These patches were occupied during the drying-up, and for years subsequently, by a dense growth of reeds; and at the present time the ditches bordering these lands, and any portion of them still covered with water, grow plentifully, tall reeds. These ancient lakelets form the lands known as 'Paluds,' where the finest quality of madder grows. The soil here, when dry, is of a light drab colour, very pulverulent, and containing about half its weight of chalk, which has been washed down from the limestone hills. When freshly turned up, this soil is dark brown, showing the presence of considerable quantities of humus.

'In the higher portions of the basin grows the quality of madder called *Rosée*. The soil here contains more clay and less chalk, and when dry it is much more tenacious and not so easily powdered in the fingers. It is, when moist, of not quite so dark a colour as the *paluds* land. The course of cultivation for the *rosée* lands is to plough up and clean the land in autumn and winter. In spring, stable or cow manure is freely applied over the ground, and then ploughed in. Beds of about three feet wide are made by cutting trenches about one foot deep, and throwing the soil on the beds. Madder-seed is now sown in drills, running lengthwise down the beds, to the number of four or five to each bed. The quantity of manure given per acre varies with the number of cattle kept by the farmers; they give as much as they can muster, as they know very well that plenty of manure increases the yield of roots. In the trenches between the madder beds, or more generally only in every other trench, white-sugar beet is always sown; probably as the beet, when growing is a very bulky, leafy plant, the beds would be too much shaded from the sun by sowing it in every drill. Nothing is done during the summer but weeding, and before winter comes on the young plant is covered entirely with earth taken from the trenches after the beet-crop (three to five tons per acre) is removed. Next spring and summer nothing but weeding is done, if we except plucking the seed and sowing beet-root in the trenches which were left vacant the former year. In the late autumn, or about October, the crop is generally dug up, or at eighteen months old. The farmers know perfectly well that to leave the madder in the ground another year, or in all thirty months, is a gain to them both in quantity and quality, but they are generally poor, the French laws of inheritance tending to constantly subdivide the lands into very small farms, and they are obliged to realise upon the crop as soon as they possibly can, which is as soon as the roots are of a saleable size. The paluds madder is always planted in the spring, not sown, the plants being obtained from the year-old crops. I could not ascertain why this difference is made, further than that it is found to suit paluds land better than rosée.

'On the two great cardinal points I satisfied myself, viz.: that manure is always given, and that no artificial irrigation is practised, the natural freshness of the soil being sufficient. The farmers, however, always look for rain in the spring to facilitate the germination of the seed, and in autumn to facilitate the digging-up the roots; for the rest of the year it is not of any importance to have rain. Rotation of crops is usually practised, though in some districts madder is grown year after year upon the same soil, by giving plenty of manure. This, however, is not considered a wise plan, and all the farmers I talked with condemned it. The usual rotation is one madder crop, then a crop of wheat, and lastly lucerne for one or two years, generally the latter, lucerne being a good paying crop. I saw in October lucerne being cut and made into hay for the fourth time that year, and even then a splendid crop. Where it is practicable, they irrigate the lucerne three or four times a year. In many places this is very easy, by damming across one of the numerous streamlets of the fountain of Vaucluse water, so as to cause the water to cover the adjacent land. Thus, once manuring, with irrigation, lasts six years.

'The roots when pulled are spread out on sheets on the ground and dried in the sun, and sold in this state to the merchant or grinder. The farmers deliver them as damp as they dare; as soon as a bundle of them, taken in the hand and twisted round, breaks easily, the roots are considered commercially dry. On being stove-dried for grinding, the dried roots lose for paluds, 20 per cent.; for rosée, 18 per cent.

'The digging up of madder is evidently the most expensive part of the business, but it is not surprising when you see the leisurely way in which they go about it: a man digs down a breadth of a bed, and then puts down his *louche* (a sort of spade-hoe) and picks out the madder roots, shakes them, and throws them into a basket. By hiring children to follow the digger, to pick up and clear the roots, a great saving could be effected. A madder-digger gets three francs a day; the ordinary wages for other labourers is two and a half francs per day. It would seem easy to adapt horse machinery to digging up madder. I was told as one reason why the roots are often pulled up at eighteen months old, that if left in the ground longer they rotted; this, however, is only said of low-lying lands, and is not the case near the mountains. I am inclined to think, however, that poverty is more frequently the cause.

'I saw near Pernes, in the paluds country, some splendid madder that had been forty-two months in the ground; the farmer had been too busy in the autumn of 1865 to pull it at the usual time, and knew, he said, that he should be rather a gainer than a loser by letting it stay in the ground another year. This madder had all the appearance of good Turkey madder; and a French madder-grinder and garancine-maker, who was with me, told me that he had never seen any so good before.

'The rent of good madder-land is high. About Avignon the land that grows rosée roots is let at 20 francs to 25 francs per eminée per annum; an eminée being one-tenth of an hectare, or about a quarter acre English.[1] The rent of paluds land, near Orange and Pernes, is 30 francs to 35 francs per eminée; so that an acre (English) of rosée lands lets at 64*s.* to 80*s.* per annum. An acre of paluds land lets at from 96*s.* to 112*s.* per acre. The yield per acre is two tons for paluds roots; for rosée roots it is not so much.[2] The present price of rosée roots, as delivered by the farmer, is 55 francs per 100 kilos.; of paluds, 65 francs per 100 kilos. These prices correspond to 22*l.* per ton for rosée, and 26*l.* per ton for paluds. These prices are exceptionally low; and a madder-grinder told me that 55 francs per 100 kilos. only about covered the cost of rent, manure, and labour, and that 75 francs was a good paying price; 75 francs is at the rate of 30*l.* per ton. Colza-oil cake is used as a manure for grain crops and lucerne, when not following madder, but it does not suit madder—good farm-yard manure being what is required; superphosphate of lime does not appear to have been tried.

'Madder of very fine quality, almost paluds, is now grown in the alluvial lands of the Bouches du Rhône, near Arles, and even down nearly to Marseilles. This land is impregnated with salt, and I was told more than once that a little salt as a top dressing was useful to improve the yield of the lands in the Comtat of Avignon. It is a curious coincidence that in the district where madder is principally cultivated in Spain—that is, between Segovia and Valladolid—there are large salt lakes, though almost in the centre of Spain; indeed, salt is made from some of them.'

The following, extracted from 'A Practical Handbook on Dyeing and Calico-

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[1] The eminée varies in size in different parts of the country; at Entraignes (terrains paluds) it contains 7 ares 85 centiares, at Avignon 8 ares 54 centiares, and at Orange 5 ares 84 centiares.

[2] This quantity is somewhat above the average. According to Mr. Pernod, an eminent garancine manufacturer at Avignon, 5 ares 84 centiares (Avignon eminée) yield 800 kilogrammes of fresh madder roots, equal to 200 kilogrammes of dry roots; one are or 100 square mètres equals 0·0247 of an English acre; 5·84 × ·0247 = 0·144248 acres, and 200 ÷ ·144248 = 1386·5 kilos, which × 2·2 = 3,050 lbs., or 27 cwts. 0·26 dry rosée roots per acre. This is for 18 months old roots. The quantity produced of 30 months old roots is one-third more, or an increased weight of one-third by keeping the roots another year in the ground, giving on above data 36 cwts. 1 qr. 6 lbs. for 30 months roots.

Printing by William Crookes, F.R.S., contains some instructive matter connected with the application of mordants in the use of madder:—

'Aluminate of soda is largely made and used in France, since the discovery of the extensive deposits of bauxite in the southern parts of that country. It is obtained by roasting, in a reverberatory furnace, a mixture of soda-ash and bauxite, until a small sample taken from the fritted mass ceases to effervesce with acids. When the operation is finished, the aluminate of soda is extracted by lixiviation with boiling water, and the solution evaporated to dryness. It is a coarse powder, exhibiting a slightly greenish colour, due to a trace of vanadium. It is infusible at the highest furnace-heat, and readily soluble in hot and cold water. Dilute solutions (sp. gr. 1·072 to 1·089 = 14 and 17° Tw.) remain limpid and clear for a long time, but stronger solutions (sp. gr. 1·3 to 1·37 = 62° to 71½° Tw.) deposit granular alumina, while the supernatant liquor contains a subaluminate and excess of caustic soda. This aluminate of soda agrees in its properties with the corresponding potassa-salt. See ALUMINATE OF SODA; BAUXITE.

'Since bauxite is a very pure native hydrate of alumina, the aluminate of soda prepared with it is used for the production of acetate of alumina in the following manner:—The aluminate of soda is precipitated by the addition of a very slight excess of hydrochloric acid; the gelatinous alumina thus obtained is thoroughly washed with boiling water, and next dissolved in acetic acid. The percentage composition of the pure aluminate of soda is 47·21 soda and 52·79 alumina; the commercial product, as met with in the French market, is contaminated with about 9 per cent. of impurities, due to the presence of sulphate of soda, and chloride of sodium in the soda-ash.

'As regards the methods of fixing alumina upon woven fabrics, it must be in a perfect state of solution, while it is also necessary that the hydrate of alumina should be precipitated, in the best possible physical condition, within the fibre of the fabrics. W. Crum found that the microscopic examination of fibres mordanted with acetate of alumina and dyed, presented differences: inasmuch as, in the first instance, the coloured lake, or combination of alumina and colouring-matter, was chiefly accumulated within the central canal of the fibre; in the second case, however, the periphery of the fibre only was coloured.

'Alumina can be obtained in solution: (1) in the state of a saline solution of that base; (2) as a basic salt; (3) as a soluble modification of the earth itself; (4) in combination with alkali. Some of the salts of alumina can be brought into contact with the cotton fibre without any decomposition whatsoever ensuing, so that a simple washing in cold water eliminates all the alumina taken up. This happens, *e.g.*, with nitrate and sulphate of alumina and with alum. Whenever it may be desirable to apply such salts for the purpose of mordanting cloth it is necessary to pass the cloth, after it has been impregnated with the aluminous solution, through a bath containing substances capable of precipitating within the fibres either hydrate of alumina, or at least an insoluble basic salt of that base. Some of the salts of alumina are decomposed by moist heat (steam), thereby giving up to the fibres of the cloth the whole or a portion of the alumina on becoming converted into a basic salt. The acid set free is volatilised, or leaves the tissue. The chloride, acetate, and hyposulphite of alumina are salts of this description. These salts become fixed by exposing the saturated tissues to a warm and moist atmosphere. This result is not simply a dissociation of the constituent elements of the salt, but the intervention of the water is absolutely required for the formation of the hydrate of alumina. The action is, therefore, to be considered as a saponification, in the more extended sense of this word, as understood by chemists.

'It is here the proper place to give a few particulars concerning the process just mentioned, and known as "ageing." The mordants generally used for madder styles are the pyrolignites, or acetates of iron and alumina, which, under the influence of ageing—which we are about to describe—are so decomposed as to leave on the cloth either an insoluble oxide or a subsalt, which becomes the intermediate agent for fixing on the fabric the colouring-matters of madder. The fixing of mordants by ageing was first practically carried out by Mr. W. Crum, an eminent and highly scientific calico-printer. "On the proper ageing of printed goods," says Dr. Schunck, "depends in a great measure the success of many styles. Should a room be too hot or too dry, imperfect fixation of the colour ensues, and meagre and uneven tints are obtained in the subsequent operations." To give some idea of the importance of this step in calico-printing, we may here state that "ageing rooms," as they are called, are in several print-works of enormous dimensions, and generally constitute a separate building. Those of Messrs. Edmund Potter and Co., and Messrs. T Hogle and Sons, all at or near Manchester, may be particularised as forming quite a feature in their works. The process of ageing in calico-printing is that by which a mordant, after being applied to a cotton fabric, is placed in circumstances favourable to its being completely incorporated with and fixed in the fibre. It has generally been found desirable that calico printed with a mordant should, before dyeing, be exposed to the atmosphere for some time in the ageing room, in single folds, which generally speaking, requires several days, the object being to liberate the acetic acid from the acetates of iron or subacetates of alumina, and to oxidise the protoxide of iron. It was for many years believed that oxygen was the only necessary agent; and although some printers had observed that moisture facilitated the process, this fact was not generally known until Mr. J. Thom of Manchester claimed the introduction of moisture as an important agent in the process of ageing, in a patent which he took out in 1849. Mr. W. Crum was, however, the first printer who applied this principle practically. He describes the process as adopted at Thornliebank (near Glasgow), in the following words:—A building is employed, 48 feet long inside and 40 feet high, with a mid-wall from bottom to top, running lengthwise, so as to form two apartments, each 11 feet wide: in one of these apartments the goods first receive the moisture they require. Besides the ground floor, it has two open sparred floors, 26 feet apart, upon each of which is fixed a row of tin rollers, all long enough to contain two pieces of cloth in their breadth. The rollers being threaded, are set in motion by a small steam-engine, and the goods to be aged, which are at first placed in the ground floor, are drawn into the chamber above, where they are made to pass over and under each roller, issuing at last at the opposite end, where they are folded into bundles on one of the three stages which are placed there. These stages are partially separated from the rest of the chamber by woollen cloths. While the goods are traversing these rollers they are exposed to heat and moisture, furnished to them by steam, which is made to issue gently from three rows of trumpet-mouthed-shaped openings. The temperature is raised from 80° to 100° F. or more, a wet-bulb thermometer indicating at the same time 76° to 96° F., or always 4° less than the dry-bulb thermometer. In this arrangement 50 pieces of 25 yards each are exposed at one time; and, as each piece is a quarter of an hour under the influence of steam, 200 pieces pass through in an hour. Although workpeople need scarcely ever enter the warmest part of this chamber, a ventilator in the roof is opened when there is any considerable evolution of acetic acid. The mordant does not, however, become fully aged by this process alone, although it is acted upon as much as if it had hung a whole day in cold air. It has received, however, the requisite quantity of moisture, about 7 per cent. of the weight of the piece, and is thus enabled, if the mordant be iron, to take oxygen from the air, and to become changed with time into the sesquiacetate and sesquihydrate of oxide of iron. In order to be sufficiently aged, it must be left one, or two, or even three, days in an atmosphere still warm and moist.

'It had been ascertained long before, at Thornliebank, that exposure in single folds, after moistening, was not necessary. The experiments of the late Prof. T. Graham, on the diffusion of gases through small apertures, had served to suggest that, for the absorption of the small quantity of oxygen required, the goods might as well be wrapped up and laid in heaps. Accordingly, in the operation in question, the moistened goods are carried in bundles into the building on the opposite side of the mid-wall already mentioned, and laid upon the sparred floors, placed at heights corresponding with the stages in the first apartment. Upon these floors, 7,000 or 8,000 pieces may be laid at a time, and, since each piece is 25 yards long, 100 miles can be stored at once. It is necessary, of course, that an elevated temperature and a corresponding degree of moisture be preserved in the storing apartments, day and night, and 80° F. is sufficient with the wet-bulb thermometer at 76°. To effect this condition, a large iron pipe is placed along the ground floor underneath, and moderately heated by steam, while a row of small jets in the same position are made to project steam directly into the air of the room. The whole building is protected from external cold, and consequently from condensation of steam, by a warmed entrance-room, and by double windows, thick walls and a double roof. Small steam-pipes are also placed at other points, where they seem to be required; and the apartment which contains the rollers is specially heated when not in use by a couple of steam-pipes, which are placed under the ceiling of the ground floor.'

All who are interested in the application of mordants, and who are desirous of understanding the principles upon which the applications are made, are referred to the 'Handbook of Dyeing,' already quoted.

MADDER LAKE. The red pigment usually called *madder lake*, which is much used by painters, is made by treating madder, which has been previously washed with water, with a boiling solution of alum, filtering the red liquid, and adding a small quantity of carbonate of soda, taking care to leave an excess of alumina in solution, washing the red precipitate, which is a compound of colouring-matter and alumina, with water and drying. Persoz gives the following method for obtaining a madder lake of great brilliancy:—One part of madder, which has been previously submitted to fermentation or else washed with a solution of sulphate of soda, is treated with ten times its weight of a boiling solution of alum, containing one part of alum, for fifteen or twenty minutes. The filtered liquid is mixed, as soon as its temperature has fallen to about 100° F., with a solution of carbonate of soda containing one-eighth or one-tenth of the weight of the alum employed. This quantity is insufficient to cause any precipitate at that temperature, but on boiling the liquid, the lake falls down in the shape of a red powder. The madder must be treated several times with boiling alum-liquor, in order to extract the whole of the colouring-matter soluble in that menstruum. It is evident that these lakes contain chiefly purpurine and very little alizarine, the latter being hardly soluble in alum-liquor. See Lake.

Imports of Madder.

	1869		1870		1871		1872	
	Cwts.	Computed real value	Cwts.	Computed real value	Cwts.	Computed real value	Cwts.	Computed real value
		£		£		£		£
Madder . . .	38,139	89,536	37,820	92,683	90,706	245,070	134,207	372,563
,, Root .	105,626	321,732	135,498	339,333	150,525	376,016	109,352	271,931
,, Munjeet .	3,921	7,151	2,749	3,471	..	..	144	803
,, Garancine	30,510	202,372	42,195	275,177	27,808	220,58	43,313	285,926

MAGDALA RED. A name applied to naphthaline red.

MAGENTA. A full description of this and analogous colours will be found under Aniline Red. We extract the following from Mr. Crookes's 'Handbook of Dyeing and Calico-Printing':—

'The simplest method of testing a commercial sample of magenta both for intensity and for purity of tone, is to dissolve a known weight in boiling water and to dye with the strained decoction a known weight of fine white woollen yarn or cloth. By thus comparing different samples, their respective tinctorial power can be readily ascertained, and the presence of tarry matters, unconverted aniline, &c., may be detected by the flatness and brownish cast of the colour. Sugar is sometimes used as an adulterant. This may be detected by treating the sample with concentrated alcohol. The magenta dissolves and is filtered off, whilst the sugar remains behind undissolved.

'The following method is used to ascertain whether a magenta is a pure salt of rosaniline, or is contaminated with mauvaniline, violaniline, chrysotoluidine, &c. The colour is dissolved in as little alcohol as possible, the solution diluted with its own bulk of water or rather more, and a drop is taken up by means of a glass rod, and applied to a piece of white blotting-paper. If more than one colouring-matter is present, the different shades will diffuse themselves in concentric circles, and may be distinctly seen. This method is still more applicable to the aniline violets and blues, which are frequently heterogeneous.

'*Aniline Crimson.*—The crude magenta-cake, without any purification, is sold under this name, and is used in dyeing certain maroons, browns, clarets, and other compound colours.

'The colour well bruised or broken up into powder, is placed in a suitable stoneware vessel and well stirred up with its own weight of hydrochloric acid. During this process the fumes given off should be carefully avoided. After the colour has steeped for a short time in the acid, boiling water is added sufficient to dissolve the whole. The solution thus obtained is carefully strained, and is then ready for use. To correct the acidity of the colour, a small quantity of ammonia is added to the dye-bath. This preparation will in many cases supersede peachwood, producing brighter shades, with less trouble, and at a lower price. They are, however, more fugitive. Upon wool and silk, aniline crimson, like magenta, is a substantive colour. Upon vegetable fibres it requires to be fixed with a mordant—generally a per-salt of tin—and an astringent.'

MAGILP. A vehicle used by artists, of a gelatinous character. Much secresy prevails as to the manufacture of magilp. It appears to be essentially linseed-oil which has been exposed for some time to the oxidising influences of the air, mixed with good mastic varnish.

MAGISTERY is an old chemical term to designate white pulverulent substances, spontaneously precipitated in making certain metallic solutions; as magistery of bismuth.

MAGISTRAL, in the language of the Spanish smelters of Mexico and South America, is the roasted and pulverised copper pyrites, which is added to the ground ores of silver in their *torta*, or amalgamation-magma in the *patio* process for the purpose of decomposing the horn-silver (chloride of silver) present. For an account of this process of reduction, see SILVER.

MAGMA is the generic name of any crude mixture of mineral or organic matters in a thin pasty state.

MAGNANIER is the name given in the southern departments of France to the proprietor of a nursery in which silkworms are reared upon the great scale, or to the manager of the establishment. The word is derived from *magnans*, which signifies silkwórms in the language of the country people. See SILK.

MAGNESIA (*Magnésie*, Fr.; *Bittererde*, *Talkerde*, Ger.) is one of the earths, first proved by Sir H. Davy to be the oxide of a metal, which he called *magnesium*. It is a fine, light, white powder, without taste or smell, which requires 5,150 parts of cold water, and no less than 36,000 parts of boiling water, for its solution. Its specific gravity is 2·3. It is fusible only by the heat of the hydroxygen blowpipe. A natural hydrate exists which contains 30 per cent. of water. Magnesia changes the purple infusion of red cabbage to a bright green. It attracts carbonic acid from the air, but much more slowly than quicklime. It consists of 61·21 parts of metallic basis and 38·79 of oxygen; and has, therefore, 20 for its equivalent upon the hydrogen scale. Its only employment in the arts is for the purification of fine oil, in the preparation of varnish.

Magnesia, popularly known as *Calcined Magnesia*, may be obtained by precipitation with potash or soda from its sulphate, commonly called Epsom salt; but it is usually procured by calcining the artificial or natural carbonate. There is a heavy calcined magnesia prepared by burning the dense carbonate. Mr. Lockyer has shown, however, that a very dense and pure magnesia could be obtained by calcining the ordinary pure carbonate in large masses, and at a very high temperature.

MAGNESIA, CARBONATE OF; properly speaking, a subcarbonate, consisting of 44·69 magnesia, 35·86 carbonic acid, and 19·45 water. It is prepared by adding to the solution of the sulphate, or the chloride (the *bittern* of sea-salt evaporation works), a solution of carbonate of soda, or of carbonate of ammonia distilled from bones in iron cylinders. Mr. Hugh Lee Pattinson introduced the manufacture of carbonate of magnesia from the dolomite rocks, availing himself of the different rates of solubility of the carbonates of lime and magnesia in water saturated with carbonic acid. (See DOLOMITE.) The subcarbonate, or *magnesia alba* of the apothecary, has been proposed by Mr. E. Davy to be added by the baker to damaged flour, to counteract its acescency.

MAGNESIA, NATIVE HYDRATE OF, or *Brucite*. This mineral consists of magnesia, 68·97, water, 31·03, according to analyses by Bruce. It accompanies other magnesian minerals in serpentine at Swinaness in Unst, one of the Shetland Isles, in the Ural Mountains, in France, and opposite to New York.

MAGNESIA, SILICATES OF. Compounds of this character are abundant in the mineral kingdom. Meerschaum, French Chalk or Steatite, Talc, Serpentine, and many other minerals are silicates of magnesia. (See *these articles*.)

MAGNESIA, SULPHATE OF, (*Epsom Salts*,) is generally made by acting upon magnesian limestone with somewhat dilute sulphuric acid. The sulphate of lime precipitates, while the sulphate of magnesia remains in solution, and may be made to crystallise in quadrangular prisms, by suitable evaporation and slow cooling. Where muriatic acid may be had in profusion for the trouble of collecting it, as in the soda-works in which sea-salt is decomposed by sulphuric acid, the magnesian limestone should be first acted upon with as much of the former acid as will dissolve out the lime, and then, the residuum being treated with the latter acid, will afford a sulphate at the cheapest possible rate; from which magnesia and all its other preparations may be readily made. Or, if the equivalent quantity of calcined magnesian limestone be boiled for some time in bittern, the lime of the former will displace the magnesia from the muriatic acid of the latter. This is the most economical process for manufacturing magnesia. See DOLOMITE.

MAGNESIAN LIMESTONE. See DOLOMITE; LIMESTONE.

MAGNESITE. *Carbonate of Magnesia; Rhomb Spar.* This native carbonate of magnesia, consisting of magnesia 47·6, carbonic acid 52·4, is found with serpentine and other magnesian rocks.

MAGNESIUM. The metal obtained from magnesia. It was first procured by Bussy, although previously shown to exist by Davy. It is now made by placing potassium or sodium in a platinum crucible, covering them with chloride of magnesium, fastening down the cover of the crucible, and exposing it to the heat of a spirit-lamp. It has been prepared by Bunsen by the action of the voltaic current; and the late Dr. Matthiessen obtained it by the electrolysis of fused chloride of magnesium.

We are much indebted to M. Sonstadt for removing the obstacles in the way of obtaining magnesium on the large scale for commercial purposes. The process pursued by Sonstadt is that of Deville and Caron, somewhat modified. Magnesium may, however, be obtained in much larger quantity, by heating a mixture of 600 grains of chloride of magnesium, 100 grains of fused chloride of sodium, and 100 grains of pulverised fluoride of calcium, with 100 grains of sodium, to bright redness, in a covered earthen crucible. The magnesium is thereby obtained in globules, which are afterwards heated nearly to whiteness in a boat of compact charcoal placed within an inclined tube of the same material, through which a stream of dry hydrogen is passed. The magnesium then volatilises and condenses in the upper part of the tube. Lastly, it is re-melted with a flux composed of chloride of magnesium, chloride of sodium, and fluoride of calcium, and is thus obtained in large globules. It still, however, usually retains portions of carbon, silicium, and nitrogen, from which it may be purified by careful distillation in a current of hydrogen.

Magnesium is an easily inflammable metal; a wire of considerable thickness can be ignited in the flame of a candle, and the light evolved by the combustion is of great intensity. It has been ascertained that a wire of 0·297 millimeter diameter will give as much light as 74 stearine candles of five to the pound. The powerfully actinic character of the light has been demonstrated by Mr. Brothers, of Manchester, and Mr. Sydney Smith, both of whom have produced good pictures by its use.

The metal is neither ductile nor very malleable. It cannot be drawn, but, by employing a method devised by Dr. Matthiessen, it can be forced in a softened state through a small opening in an iron cylinder, and thus strands of wire of considerable length can be formed. The wire has been found to burn more steadily when three or four strands are twisted into a rope; and a simple clockwork arrangement will deliver such a rope to a spirit- or oil-lamp, in the flame of which it may be burned.

Alloys of Magnesium.—Dr. T. L. Phipson has paid some attention to these. In a communication to the Chemical Society, he says:—

'I have examined only a few alloys of magnesium. Unlike zinc, magnesium will not unite with mercury at the ordinary temperature of the air. With tin 85 parts, and magnesium 15 parts, I formed a very curious alloy of a beautiful lavender colour, very hard and brittle, easily pulverised, and decomposing water with considerable rapidity at ordinary temperatures. If the air has access during the formation of this alloy the mixture takes fire; and if the crucible be then suddenly withdrawn from the lamp the flame disappears, but a vivid phosphorescence ensues, and the unfused mass remains highly luminous for a considerable time. A white powdery mass, containing stannic acid and magnesia, is the result. (With platinum, according to M. Sonstadt, magnesium forms a fusible alloy; so that platinum crucibles can be easily perforated by heating magnesium in them.) Sodium and potassium unite with magnesium and form very malleable alloys, which decompose water at the ordinary temperature. It is probable that an alloy of copper and magnesium, which I have not yet obtained, would differ from brass, not only in lightness, but by decomposing water at the usual temperature with more or less rapidity.'

Photochemical Power of the Magnesium Flame.—To Professors Bunsen and Roscoe we are especially indebted for an examination of this question. Their experiments showed that a burning-surface of magnesium-wire which, seen from a point at the sea's level, has an apparent magnitude equal to that of the sun, effects on that point the same chemical action as the sun would do when shining from a cloudless sky at a height of 9° 58′ above the horizon. On comparing the chemical with the visible brightness of these two sources of light, it was found that the brightness of the sun's disc, as measured by the eye when the sun's zenith distance was 67° 22′, is 524·7 times as great as that of the burning magnesium-wire; whilst, at the same zenith distance, the chemical brightness of the sun is only 36·6 times as great. Hence the value of this light as a source of the chemically-active rays for photographic purposes becomes apparent.

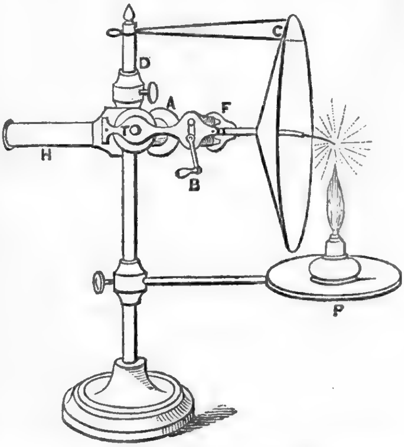
Professors Bunsen and Roscoe say in their memoir: 'The steady and equable light evolved by magnesium-wire burning in the air, and the immense chemical action thus produced, render this source of light valuable as a simpler means of obtaining a given amount of illumination expressed in our terms of measurement of light. . . The combustion of magnesium constitutes so definite and simple a source of light for the purpose of photochemical measurement that the wide distribution of this metal becomes desirable. The application of this metal as a source of light may even become of technical importance. A burning magnesium-wire of the thickness of 0·297 millimeter evolves, according to a measurement we have made, as much light as seventy-four stearine candles, of which five go to a pound. If this light lasted one minute, 0·987 meter of wire, weighing 0·1204 grain, would be burnt. In order to produce a light equal to seventy-four candles burning for ten hours whereby about 20 lbs. of stearine is consumed, 72·2 grains of magnesium would be required. The magnesium-wire can be easily prepared by forcing out the metal from a heated steel press, having a fine opening at bottom; this wire might be rolled up in coils on a spindle, which would be made to revolve by clockwork, and thus the end of the wire, guided by passing through a groove, or between rollers, could be continually pushed forward into a gas- or spirit-lamp flame, in which it would burn.'

In the reports of Mr. Brothers' experiments upon the magnesium-light, he says, 'The result of an experiment I have just tried is, that in fifty seconds, with the magnesium-light, I have obtained a good negative copy of an engraving, the copy being made in a darkened room. Another copy was made in the usual way by daylight, and in fifty seconds the result was about equal to the negative taken by the artificial light. The sun was shining, but there was a good deal of fog in the atmosphere.'

Magnesium-Lamps have been invented and manufactured by F. W. Hart, London, for photochemical and other purposes. This invention includes the use of springs and wheels for self-acting propulsion and revolving of the ignited magnesium at the same time, thereby avoiding a drooping light, which for optical illumination is a great desideratum. These lamps are only made to order, as their mechanism is considered unnecessary for ordinary purposes, the action of the simplified lamp being as follows:—

Hand-Lamp, for ribbon or one or more wires—if more than one wire, they should be twisted firmly together. Place the end in the clip on the inside of the flange of the reel A (*fig.* 1422); apply a slight pressure to the reel by turning the tension-screw T; then wind the magnesium on by turning the flange with the finger and thumb; in the more highly-finished lamps the winch, B, screws on the spindle of A for winding on quantities very regular. The loose end is then passed through the guide and feeding-rollers at F. Sufficient tension having been applied by the screw-head, T, the wire remains without uncoiling. *For use,* release the tension, and turn the winch, B, towards the reel, A. In the self-acting propelling-lamps above mentioned, a governor requires personal adjustment to the rate of burning—in the simplified *hand-lamps* the winch, B, is moved at the desired rate, which saves a considerable expense for common purposes. The wire should be ignited in the smokeless part of a flame, and *a spirit-lamp is recommended.* See Watts's 'Dictionary of Chemistry.'

1422



MAGNET. A bar of steel, which, being imbued with a peculiar condition of electrical force, is possessed of polarity. The magnet has a special employment in the mariner's compass, as from the undeviating way in which—unless strong disturbing causes are in operation—it points north and south. The magnet is used also in surveying-instruments. The use of iron in ship-building has led to a very careful examination of the influence of iron on the ship's compasses. The late Dr. Scoresby, Professor Airy, and some others, have been peculiarly distinguished in this important inquiry, and to their memoirs on the subject the reader is referred. Magnetic machines have been constructed for developing electricity, and employed for the deposition of metals. See Electro-Metallurgy.

MAGNETIC PYRITES. One of the native sulphides of iron. Its chemical composition is usually sulphur 40·15, iron 59·85. Its power of attracting the magnetic needle is probably due to the peculiar condition in which the iron exists. It is distinguished from the common pyrites (*Mundic*) by its inferior hardness and its bronze colour. See Pyrites.

MAGNETISM. A peculiar condition of electrical force. The phenomena of magnetism which are rendered in any way available in the arts are detailed in special articles; as Electro-Telegraphy, &c. &c. All bodies must now be regarded as existing in one of two known conditions of magnetism. It is understood that magnetism is manifested as a *polar force*, as in a bar of iron. Every one is familiar with the fact that a polarised bar, if free to move, places itself in a certain direction, which we call north and south. Besides iron, nickel and two or three other metals possess this property. Bismuth, silver, glass, wood, and nearly all other substances exhibit magnetic force of a different order, which is manifested in all these bodies by their placing themselves at right-angles to a magnet, or to the line of magnetic force. This condition has received the name of DIA-MAGNETISM, *which see.*

MAGNETITE. Oxydulated iron, or magnetic iron ore. One of the richest and most important ores of iron. See IRON.

MAGNET, NATIVE. See LOADSTONE and IRON.

MAHALEB. The fruit of this shrub affords a violet dye, as well as a fermented liquor like *Kirschwasser*. It is a species of cherry, cultivated in our gardens.

MAHOGANY. The wood of a tree (*Swietenia Mahagoni*), which is a native of the West Indies. This wood appears to have been first brought to England in 1724.

SPANISH mahogany is imported from Cuba, St. Domingo, the Spanish Main, and several of the West India Islands, in logs about 26 inches square, and 10 feet long. Its general character is well known from its extensive use in cabinet-work.

HONDURAS mahogany is generally lighter than the Spanish, and more open and irregular in its grain. This is imported in large logs, many of 4 feet square and 18 feet in length. Planks are sometimes obtained of 7 feet in width. According to Mr. Chief-Justice Temple, 'the cutting commences in the month of August. In April or May, in which months the ground has become perfectly hard from the continued dry weather, the wood is carried upon trucks drawn by bullocks to the water side; and about the middle of June, when the rivers are swollen by the floods, the logs are floated down about 10 miles from the mouths of the different rivers, where they are confined by a heavy boom drawn across the stream. Here the owners select their respective logs, form them into rafts, and so float them down to the sea. The mahogany is always trucked in the middle of the night, the cattle not being able to perform such laborious work during the heat of the day. It is a picturesque and striking scene—this midnight trucking. The lowing of the oxen, the creaking of the wheels, the shrill cries of the men, the resounding crack of their whips, and the red glare of their pine torches in the midst of the dense dark forest, produce an effect approaching to sublimity.

'An impression has latterly existed that almost all the mahogany in British Honduras has been cut. This, however, is a mistake. There is sufficient wood in the country, both on granted and ungranted land, to supply the European as well as the American markets for many years to come. A considerable quantity of mahogany has been, within the last few years, cut in the state of Honduras and on the Mosquito shore; but the mahogany-works in the former country have been almost entirely abandoned, partly on account of the wood, which is accessible, being nearly all cut, and partly on account of the extra freight and insurance which are required when vessels are loaded on that coast. From the Mosquito shore very few cargoes have been lately sent, for the wood which grows there, although it is very large, is of inferior quality. The mahogany-tree requires a rich dry soil. The best mahogany is found to the north of the river of Belize. In consequence of the nature of the soil in that district, in which there is a great quantity of limestone, the mahogany is longer coming to maturity, but, when fully grown, it is of a harder and firmer texture than that which is found in the southern portion of the settlement. There is no wood more durable than mahogany, and none that is so generally useful. It is stated in a little book called the "Mahogany-Tree" that furniture is being made, in the royal dockyards, out of the beautiful mahogany found in breaking up the old line-of-battle ship the *Gibraltar*, which was built in Havana 100 years ago. The English and French Governments purchase yearly a large amount of mahogany for their dockyards. During the last year the British Government required 12,000 tons, paying 10*l.* 17*s.* 6*d.* per ton. The French government took 3,000 tons at the same price. The royal yacht is built principally of Honduras mahogany. Private ship-builders are, however, reluctant to make use of mahogany for their vessels, as Lloyd's Committee exclude all ships of 12 years' standing in which the floors, futtocks, top-timber, keelson, stem and stern-post, transoms, knightheads, hawse-timbers, apron, and dead wood, are made of mahogany.

'Mahogany vessels of 10 years' standing they admit, but even these, I am informed, it is their intention very shortly to exclude. The reason which they assign is, that mahogany differs very much in quality, and it is impossible to know when a ship is built of good or bad wood. But this difference in quality depends entirely upon the district in which it has grown. If they restricted the ship-builders to the northern wood, they might admit vessels of 12 years' standing without any risk. In the year 1846 the Honduras merchants presented a memorial to Lloyd's Committee, praying for a removal of the existing limitations to the general use of mahogany in the building of vessels of the highest class. Attached to this memorial were numerous certificates from persons well qualified to give an opinion on the subject, speaking in the highest terms of mahogany for ship-building. Captain E. Chappel, R.N., Secretary of the Royal Mail Steam Packet Company, says he "has seen the *Gibraltar*, 80-gun ship, which was broken up at Pembroke. *This ship is entirely of mahogany;* captured of the Spaniards in 1780; *all her timbers sound as when put into her.* Tables for the Navy made of the timbers of the *Gibraltar.* The steamer *Forth*, built by Mr. Menzies of Leith, has as much mahogany put into her as could be obtained. The use of mahogany ought to be the *rule*, and not the exception." The qualities of mahogany, which render it peculiarly fitted for ship-building, are its lightness and buoyancy, its freedom from dry-rot, and its non-liability to shrink or warp. The price of mahogany varies according to the size, figure, and quality of the wood. One tree from the northern districts, which was cut into three logs, sold for 1,800*l.*, or 10*s.* per superficial foot of 1 inch; southern wood of small size and inferior quality has been sold at 3½*d.* per foot. The present prices in London for small-sized plain mahogany are from 5*d.* to 6*d.* per foot; for large-sized plain, from 7*d.* to 10*d.*; and for large, of good quality and figured, from 9*d.* to 1*s.* 6*d.*

'The yearly average quantity of mahogany exported from Honduras during the last ten years is about 8,000,000 feet, equal to 20,000 tons, or 200,000 tons in the whole ten years, requiring 160,000 trees.'

AFRICAN mahogany (*Swietenia senegalensis*), from Gambia, has been used of late years for curriers' tables, mangles, &c., and may be used for turning. It is denied by some authors to be a *Swietenia*; but, if not so, it is a very closely-allied genus.

There are two or three varieties of the *Swietenia* in the East Indies which are ornamental woods, but not mahogany.

The importance of this wood will be seen from the following statement of the *Imports* of mahogany in 1868–70, and 1872:—

	1868		1869		1870		1872	
	Tons	Computed real value	Tons	Computed real value	Tons	Computed real value	Tons	Computed real value
		£		£		£		£
From France	..	..	..	..	..	..	1,244	19,193
" Cuba	5,207	46.598	1,726	16,967	980	9,912	..	..
" Curaçoa	271	2,599	753	7,154	814	8,243	..	..
" Hayti and St. Domingo .	1,290	16,163	1,041	12,466	2,267	26,185	1,090	11,235
" United States (near Atlantic ports) . . .	177	1,549	..	..	..	..	660	7,920
" Ports on the Pacific .	137	1,165	..	..	..	..	..	..
" British West Indies .	..	..	..	..	..	..	671	6,046
" Mexico	20,479	149,835	24,038	169,687	15,585	116,585	15,090	182,318
" Central America . .	5,705	43,002	6,537	45,759	6,871	51,533	4,757	50,548
" British Honduras . .	7,979	65,921	11,177	91,484	3,542	27,640	7,705	66,261
" Other parts . . .	680	5,900	1,980	16,231	2,673	21,260	2,703	32,269
Total . .	41,925	332,732	47,252	359,748	32,732	261,358	33,920	375,790

MAIZE. A genus of monocotyledonous plants belonging to the natural order *Gramineæ*—the grasses. There are only two species known, and these both belong to America. The *Zea mays* is the Indian corn or common maize; and the *Zea caragua*, the Chilian maize or Valparaiso corn. Both these varieties are largely cultivated as articles of food.

MAJOLICA, known also as Faenza and Raffaelle ware. A term for soft enamelled pottery, first introduced into Italy from Majorca about the twelfth century, and which was the work of the Moors.

The distinguishing points of the so-called majolica are coarseness of ware, and an opaque white enamel containing binoxide of tin, and decorated in colours. A large class ascribed, although possibly on insufficient grounds, to Valentia, is characterised by elaborate conformity of pattern, flushed with metallic lustre, on a greyish-white ground.

Of the positively Italian wares, though they were so greatly in request that most of the cities of the Romagna instituted manufactories of them, but little can be ascertained prior to the sixteenth century.

The towns most celebrated after A.D. 1500 for their artistic productions are Pesaro, Gubio, Ascanio, Bologna, Citacastellana, Ferrara, Forli, Fynlina, Pisa, Perugia, Rimini, Sienna, and Spello; and the first is considered the earliest site of a manufactory in Italy, notwithstanding the attempts of the ingenious Eugène Piot in favour of Deruta. So early as 1509 Guidobolato della Rovere, duke of Urbino, granted a patent to Jacques Lanfranco of Pesaro, for 'the application of gold to the Italian faïence,' by which is probably intended that lustre of a golden colour which so brilliantly sheds its prismatic hue on the fictile performances of this period. The next in antiquity is Gubio, which boasted, in Giorgio Andriolio, of one of the most famous masters in his art. In 1511, and subsequently, he, improving on the invention of Lanfranco, gave to his wares a ruby splendour, restricted to his works alone; for the artist and his secret died together. His works are usually inscribed at the back M^o. G^o. (Maestro Giorgio), which title he assumed on his ennoblement. At Gubio, also, Giorgio's son Vincent is said to have laboured in the same department.

It was, however, during a period extending from 1520 to 1560 that these wares attained perfection. The classical designs of Raffaelle, of Giulio Romano, and of Marc Antonio, were adopted and correctly developed; the most graceful figure-compositions, selected from the Grecian and Roman mythologies, were surrounded by borders of imaginative arabesques. The colours, less brilliant than before, were now more harmoniously combined, while the glaze became more transparent, and more evenly applied then ever. Plates, dishes, vases, cisterns, fountains, now came into being in full magnificence, while goblets, salt-cellars, and other appendages to the table receive the same careful ornamentation with works of greater pretension but less utility.

At Pesaro, in 1542, flourished Geronimo, and in 1550, Mathieu, when large dishes were first made, having a profusion of ornaments executed in relief. With these artists successfully competed Terenzio, son of Mathieu; Battista Franco, a skilful designer, entrusted with the direction of the works; Taddeo Zuccaro and the two Raffaelles—one Ciarla, the other dell Colle—both for a long time confounded with the immortal Sanzio. There, too, worked the brothers Flaminio, and Orazzio Fontana, of Urbino, on the dinner service which Guidobardo caused to be made for Charles V. and Philip II. Orazzio also worked at Castel Durante and Florence, as did the Chevalier Piccolpesso, a talented painter, and the author of a work on pottery. Rivalling also the above in fame, were Guido Selvaggio of Faenza, Francisco Xante de Rovigio, who was a support of the manufactory at Urbino, Frederico Brandini, and Guido Durantino. The works of Luca della Robbia gave much celebrity to the ware, owing to the brilliancy of his colours, the modelled relief of his designs, and the hardness of his enamel. The Dukes of Urbino patronized the art for nearly two hundred years; and the productions they issued are generally known as Raffaelle ware.

For an historical account of majolica, see Mr. Drury Fortnum's elaborate 'Descriptive Catalogue of the Majolica in the South Kensington Museum,' 1873.

MALACHITE, or *mountain green*, is native carbonate of copper of a beautiful green colour, with variegated radiations and zones; spec. grav. 3·5; it scratches calcspar, but not fluor-spar; by calcination it affords water and turns black. Its solution in the acids deposits copper upon a plate of iron plunged into it. Its consists of carbonic acid, 18·5; protoxide of copper, 72·2; water, 9·3.

It is found in great quantities and of a remarkably fine character, in the copper mines of the Ural mountains, and is in Russia manufactured into various kinds of furniture and highly ornamental articles. A very fine malachite has been obtained from the Burra-Burra mines in South Australia. It is found to exist in large quantities in Central Africa. See COPPER.

MALATES are saline compounds of the bases with malic acid.

MALE FERN. *Lastrea* (*Aspidium*) *Filix-mas.* This fern grows in all parts of Europe and most parts of America, between New York and Virginia. Its root (rhizome) has been used for tanning. The best root is about 6 inches long and an inch broad; externally it is of a brown colour, internally yellowish or reddish white, with a peculiar but not very strong odour, and a sweetish bitter-astringent taste. Morrin states that the root contains volatile oil, fatty matter, gallic acid, acetic acid, tannin, uncrystallizable sugar, starch, ligneous matter, and gelatiniform matter. The root is collected in May and September.

MALIC ACID. (*Acide malique*, Fr.; *Aepfelsäure*, Ger.) This acid exists in the juices of many fruits and plants alone, or associated with the citric, tartaric, and oxalic acids; and occasionally combined with potash or lime. Unripe apples, sloes, barberries, the berries of the mountain-ash, elder berries, currants, gooseberries, strawberries, raspberries, bilberries, brambleberries, whortleberries, cherries, and ananas, afford malic acid; the house-leek and purslane contain the malate of lime.

The acid may be obtained most conveniently from the juice of the berries of the mountain-ash or barberries. This must be clarified, by mixing it with white-of-egg, and heating the mixture to ebullition; then filtering, digesting the clear liquor with carbonate of lead, till it becomes neutral; and evaporating the saline solution, till crystals of malate of lead be obtained. These are to be washed with cold water, and purified by re-crystallization. On dissolving the white salt in water, and passing a stream of sulphuretted hydrogen through the solution, the lead will be all separated in the form of a sulphide, and the liquor, after filtration and evaporation, will yield yellow granular crystals, or cauliflower concretions, of malic acid, which may be blanched by re-dissolution and digestion with bone-black, and re-crystallization.

Malic acid has no smell, but a very sour taste, deliquesces by absorption of moisture from the air, is soluble in alcohol, fuses at 150° Fahr., is decomposed at a heat of 348°, and affords by distillation a peculiar acid, the pyromalic. It consists, in 100 parts, of 41·47 carbon, of 3·51 hydrogen, and 55·02 oxygen; having nearly the same composition as citric acid. A crude malic acid might be economically extracted from the fruit of the mountain-ash, applicable to many purposes; but it has not hitherto been manufactured on the great scale.

MALLEABILITY is the property belonging to certain metals of being extended under the hammer by beating, or under the roller. Gold is a remarkable example of a malleable metal.

MALLEABLE IRON. See IRON.

MALM ROCK. A local name for the sandstones of Sussex and Surrey, called also *fire-stone*. It belongs to the Upper Greensand formation. This *Malm* forms the soil which produces the greater part of the hops for which these counties are celebrated. See SANDSTONE.

MALTHA. *Bitume glutineux*, or mineral pitch. It dissolves in alcohol, as also in naphtha, and oil of turpentine. It seems to be inspissated petroleum.

MALTING. The process by which barley or other grain is prepared by germination under artificial conditions, for the purpose of brewing. The changes produced in its constituents, and the requisite properties of good malt, having been already given in the article BEER, we now proceed to describe the requisites of a malt-house, and the mode of operation.

The necessary apparatus for the production of malt is extremely simple: that is to say, first, a cistern or vessel for steeping the grain; secondly, a floor on which it may be thinly spread and allowed to germinate; and, lastly, a kiln or stove in which the newly-formed malt may be dried. These need not be of any specific size, neither is any special position, or arrangement needed; but in this country, from the large amount of duty levied on this manufacture, fiscal regulations interfere with, and influence the whole arrangement.

The regulations as to the manufacture of malt are embodied in the acts 7 & 8 Geo. 4. c. 52, and 11 Geo. 4. c. 17. The former act is an admirable specimen of legislative injustice; the latter was intended to ameliorate the provisions of its predecessor, and does, in a degree, effect that object, The first contains no less than 83 clauses; and the regulations in it are enforced by 106 penalties, amounting in the aggregate to the incredible sum of 15,000*l.* How much of this is negatived by the subsequent act it is not very easy to determine, though, as far as it goes, the effect of No. 2 is to stultify the regulations of No. 1. The cistern or steeping vessel must be of a determinate form and construction; it must have been approved of by a supervising officer; its cubical contents must have been very accurately ascertained by actual admeasurement, and it must be placed in such a situation that the officer gauging it may have sufficient light, and a clear open space of 48 inches, at the least, above every part of such cistern, for the purpose of facilitating the process of gauging; and, lastly, if such light be an impossibility, from local obstacles, the maltster must enter into an engagement to keep, at his own expense, lamps or candles burning, for the convenience of the officer. From what we have now said, as well as from the notoriously uncertain character of grain, it might naturally be inferred that the process of steeping would be left entirely to the judgment of the maltster, who would determine according to his experience, and the nature of the resulting phenomena, when the grain had been steeped long enough in the water, and when it had not. The law, however, allows him no such privilege; whether the grain be old or dry, or new and moist, is all one,—'maltsters are required to keep their corn or grain covered with water for the full space of 40 hours, under the penalty of 100*l.*' Nor will any change occurring in the appearance of the grain, and seeming to require its immediate removal, justify or excuse the maltster in so doing, unless indeed he shall have anticipated the occurrence by giving notice of his intention to do so in his original notice *'to wet'*—which must date 24 hours previous to commencing that operation,—and to give the day and hour of the day for beginning the steep,—all under the usual penalty of 100*l.* Nor may he 'begin to wet at any other time than between the hours of eight in the morning and two in the afternoon,' under a penalty of 100*l.*, nor may he take corn or grain from any cistern at any other time than between the hours of seven in the morning and four in the afternoon. To empty corn or grain out of any cistern, until the expiration of ninety-six hours from the time of the last preceding emptying of any cistern in the establishment, involves a penalty of 200*l.*; and the same infliction occurs, 'if the corn or grain be not emptied out of all such cisterns at one and the same time, or within three hours after the clearing of the first cistern was commenced.'

Maltsters are not to mix, either on the floor or kiln, any corn or grain of one wetting with corn or grain of another wetting, under a penalty of 100*l.* What is termed the couch, or place in which the grain, after being steeped, is laid together for the purpose of germination, is a supplementary apparatus of excise ingenuity, and no way necessary to the success of the malting process. Here the grain, after having been gauged in the steep, is again to be gauged with great care; and if the maltster should tread or compress the couch, so as to diminish its bulk, a penalty of 100*l.* is imposed, though it is obvious that a power of loosening or compressing this couch according to its temperature would greatly improve the formation of malt. However, 'all corn or grain emptied into the couch-frame is to be laid flat and level by the maltster, and so kept 24 hours at the least,' and similarly the floors are all to be placed level on pain of 100*l.* fine, so that any experimental essay at improvement is very likely to end in the Court of Exchequer. Again, it frequently happens, or rather we should say, it generally happens, that too little water is absorbed by the grain during the operation of steeping; the consequence of which is, that after being removed from the couch to the floor, the grain desiccates, and, ceasing to germinate, speedily evolves a sickly odour, and becomes mouldy,—the incipient radicles at the same time drying and shrinking up for want of moisture; in fact, the grain withers and perishes from the effect of drought, This condition is very frequent about the third and fourth day from the couch, and is easily and effectually put a stop to by the application of a little water. But now comes a rather awkward dilemma for the maltster: if the grain continue on the floor without being sprinkled, it is greatly damaged or altogether spoilt; if water be sprinkled upon it to restore vitality, the law says that 'corn or grain, making into malt, must not be wetted or sprinkled with water before the expiration of 12 days, or 288 hours, after the same shall have been taken from or out of the cistern, under a penalty of 200*l.*' Where, however, the steep has lasted for the full period of 50 hours, and where, consequently, the want of water is less likely to be felt, the maltster may sprinkle at the end of six days, or 144 hours; but in no case less than this,—though, as we have stated, the great urgency for the sprinkling process occurs generally on the third day; and it is an undeniable fact, that, in spite of the heavy risk incurred, maltsters do almost invariably sprinkle their floors at about this period, and are thus driven to the necessity of trusting in the good faith and discretion of some workman, to the injury of both parties. But the discriminating power confided to excise officers in these matters is incredible. 'Whenever there shall be reason to suspect, from the appearance of the grain on the floor, that it has been illegally wetted or sprinkled, the officer must give immediate notice to the maltster, or his servant, of such suspicion, and make a memorandum thereof, upon the specimen-paper, and in the memorandum-book, mentioning whether anything, and what, was stated by such maltster or any person on his behalf," &c. Nay, the views of the officer are ordered to be put on record, as to an immense number of fortuitous circumstances, all of which, of course, received an unfavourable signification: for instance, 'how the kiln was loaded, and whether fed by a brisk or slow fire?—whether the house seemed in a state for running or wetting, or committing any other and what fraud?—what the trader says, and what character he bears in his concerns with the revenue?'—and so on, in the most arbitrary spirit. Indeed, the officer is specially instructed to make sudden and unexpected returns or visits, at unusual periods, so as to discover any suspicious indications. Again, of the three separate gauges of malt which he may take, whether in the cistern, in the couch, or on the floor, the officer must select the largest for charging duty upon. Thus, if in the cistern he finds 78¼ bushels indicated, in the couch subsequently 81½ indicated, and on the floor 83½, then the latter is preferred; and so with regard to the highest wherever found,—the order being that 'when the cistern or couch gauge is equal to or exceeds the floor gauge, then the best cistern or couch gauge will be the charge; but if that be less than the floor gauge, then the floor gauge will be the charge.' Any accident or loss arising after the cistern gauge is therefore thrown wholly on the maltster, who, far from being able to employ his ingenuity in the improvement of his business processes, finds himself more than fully occupied in a perpetual effort to protect his interests from fiscal regulations conceived in a most hostile spirit. The carelessness and ignorance of common workmen may at any moment subject the most honest maltster in the kingdom, not merely to charges of dishonesty, but even to penal inflictions; which have ceased to carry moral degradation with them, only because of the popular belief of their injustice. It would be impossible, nor is it requisite, to follow out or recapitulate the innumerable annoyances to which the manufacturer of malt is subjected at present: we have thus briefly noted down a few, in order that the admirers of Bavarian and other foreign beers may take into account the very different state of the malt manufacture in this country, as compared with that brought about by an unrestricted liberty to use or apply any means which the nature of the grain, the condition of the atmosphere, or other accidental circumstances, may require during the process of germination.

Having thus seen the restrictions imposed by the legislature, we need only indicate that the capacities of the cistern, the couch, and the kiln should be adapted to contain respectively the whole quantity of barley or malt made at one steeping, and this should again have reference to the space allotted to the floor, which should allow of at least three steepings to be worked on it without interference in their different stages of growth and withering.

The process of malting consists of three successive operations: the steeping; the couching, sweating, flooring; and the kiln-drying.

It often happens from various reasons that the importance of extreme care in the selection of barley for malting is overlooked, but the injurious consequences resulting from such a laxity are so great that they cannot be too strongly impressed upon the attention of the party entrusted with this duty. All barleys that have been weathered in the field, or have got mow-burnt or musty in the stack, should be rigidly rejected; they are so easily detected that there is no room for accidental oversight. Weathered barley has a dull and often a dirty appearance, quite distinct from the bright shotty character of good samples, and frequently a sprouted corn or two may be seen amongst them, but the last is the least evil of the three, as the sprouted corns may to some extent be removed by carefully swimming the barley (at the time the cistern is charged) and floating off the lighter grains. But with mow-burnt and musty barley the grain has suffered so much that a sound wort out of malt made from mow-burnt barley cannot be obtained. This evil arises chiefly from the barley having been stacked in an insufficiently dry state; subsequently it has become overheated and its germinating principle destroyed; there is no remedy, it cannot be reclaimed, it is spoilt for malting purposes, more or less according to the circumstances immediately attending it. It may be detected by a peculiarly faint, sickly smell, perhaps the word 'stink' more nearly describes it; in addition to that, it may be at once suspected if some of the grains have a discolouration varying from red to black at the radicle end; such grains when thrown into the couch after steeping will often exhibit a brownish-red appearance from end to end; if broken they will display a red-tinted kernel and show an unmistakeable rottenness; on the floor they will impart that odour of rotten apples, so disheartening to the careful maltster, especially if he be brewer also; and after being dried on the kiln, a minute examination of them will disclose a kernel of a yellowish and sometimes a brownish tinge, which otherwise ought to be perfectly white and flowery. Beer brewed from such malt is liable to ferment with uncontrollable violence, and will soon turn sourish, bad, or stinking, according to the degree of injury the barley has suffered.

Musty barley of course can easily be detected by the smell, and a slight appearance of mould may generally be detected upon the ends and belly of the grain; if it is very slight indeed it need not condemn an otherwise good sample, but if it arises from being overheated in the hold of a vessel it should not be malted. Broken and bruised corns, and corns crushed by the feet or shovel upon the withering floor, have precisely the same effect and result as mow-burnt barley; for this reason, therefore, the thrashing-machines now in such general use have need of great improvement, as they break the corns to a fearful extent, the more so when the season has been exceptionally dry, and the finest and boldest corns suffer most.

Another unfavourable symptom is when the beard has not been entirely removed, some of the corns retaining portions of it attached; this is an indication that the mellowing in the stack has been imperfect when the grain was thrashed, the beard has therefore remained tough, and the operation has been unable therefore to detach them: it is generally attendant on weathered grain.

The Malting.—It is a good plan as a rule to have all barley shot into its binn as soon as possible, and there allowed to remain till it is wanted for malting; the mellowing is thereby somewhat encouraged, especially so if the season has been a very dry one, for the barley is likely to be intractable; it is advisable then to let it remain in heap for some weeks with that purpose.

But if on putting the hand into the sacks the feeling of sharpness and briskness is wanting, too much moisture may be suspected: it should then remain in dry sacks, or, if thought requisite, should be dried with a slow fire upon the kiln and turned frequently, after which it should be thoroughly cooled, and thrown into heap to mellow.

Whenever practicable, samples differing from each other should never be mixed before malting, but when unavoidable only such barleys should be mixed as are of the same weight per imperial bushel, the same in character and condition, and from similar districts, otherwise there will be a harassing irregularity upon the floor. And now before commencing operations, perhaps a word or two about the amount of work a man should do would not be out of place.

Previous to the operation of steeping, it will be found most profitable that the barley should be very thoroughly cleansed: all dirt, earth, stones, light grains, and small ones, should be carefully screened and swam out of it (for it is a waste to pay duty and wages for such things, and what is of more consequence, they tend to injure the quality of the malt while on the floors), and the steep commences.

It is a good arrangement to have at the overflow-end of the cistern a sieve or wire trough placed a few inches below the overflow on the outside of the cistern, so that the surplus water shall easily float away the light grains from the surface as they rise; there they will collect, and may eventually be taken away, dried on the kiln, and used for feeding purposes. The draining ability of the cistern should be as ample and expeditious as possible, and the water-supply should be equally good; some maltsters with commendable prudence provide a sort of shower-bath arrangement over their cisterns in place of the water-tap.

The steeping is performed in large cisterns made of wood or stone, which being filled with clear water up to a certain height, a quantity of barley is shot into them, and well stirred about with rakes.

The good grain is heavy and subsides; the lighter grains, which float on the surface, are the damaged ones, and should be skimmed off, for they would injure the quality of the malt and the flavour of the beer made with it. They seldom amount to more than 2 per cent.

More barley is successively emptied into the steep-cistern, till the water stands only a few inches, about five, above its surface; when this is levelled very carefully, and every light seed is removed.

The steep lasts from 40 to 84 hours, according to the circumstances of the season, condition, and weight per imperial bushel; new barley requiring a longer period than old, and big requiring much less time than barley.

In England it is the common practice, in order to escape as much as possible the excise duty, to allow the barley as a rule only 50 hours, but this is not sufficient for heavy or strong barleys: 60, 72, or even 84 hours will be found much more advantageous to the saccharific and friable qualities of the malt produced, and where the maltster is also the brewer it will well repay him the little extra excise duty he may pay on account of it, and the loss by solution in the steep-water will be found altogether inconsiderable. The Munich maltsters usually allow 96 hours, and take for their criterion that the pip shall have swollen almost to bursting, before the steeping is considered sufficient.

During this steep, carbonic acid is evolved from the grains, and combines with the water, which at the same time acquires a yellowish tinge and a strawy smell, from dissolving some of the extractive matter of the barley husks. The grain imbibes about one-half of its weight of water and increases in size by about one-fifth. By losing this extract the husk becomes about one-seventieth lighter in weight, and paler in colour.

The duration of the steep depends in some measure upon the temperature and state of humidity of the atmosphere, and the temperature and constitution of the water, and is the shorter the warmer the season.

The water most suitable for malting purposes is most certainly fresh spring-water from deep sources, at the temperature of about 52° Fahr.; this is generally obtainable in England; surface-water is not estimable, first, on account of its variable temperature, secondly, because it contains a variable amount of organic matter, and thirdly, because its solvent power is greater; whereas the salts of lime held in solution by nearly all spring-waters have a very beneficial effect upon the barley, as to some extent they neutralise the acid tendency, and must or mould.

Steeping has for its object, to expand the farina of the barley with humidity, and thus prepare the seed for germination, in the same way as the moisture of the earth prepares for the growth of the radicle and plumula in the seed. Too long continuance in the steep is injurious; because it prevents the germination at the proper time, and thereby exhausts a portion of the vegetative power: it causes also an abstraction of saccharine matter by the water. The maceration or steep is known to be complete when the skin of the barley has lost all wrinkle or curl, can be easily transfixed with a needle, and is swollen to its fullest size. The following is reckoned a good test:—If a barleycorn, when pressed between the thumb and fingers, continues entire in its husk, it is not sufficiently steeped; but if it sheds its flour on the fingers, it is ready.

When the substance exudes in the form of a milky juice, the steep has been too long continued, and the barley is spoiled for germination.

Unhealthy, damaged, and mutilated corns, frequently become pasty in the cistern, long before the sound portion of the charge has been steeped enough, and this the sooner, in proportion to the amount of injury the grain has suffered. All such grains are apt to become very damaging upon the withering floor, and to avoid this, and increase the profits as much as possible, it is a rule with some maltsters that the more indifferent a sample of barley is, the less steep must be given to it; he must force the acrospire on, by thick and warm floors, that it may be put on the kiln as quickly as possible, after it is wetted; by this means, the sample saves its appearance very considerably; but although the decomposing corns do not stink and mould quite so soon when thus worked, as they would if treated otherwise, their mischievous tendency is not at all diminished; for, by the short steep allowed, the sound corns are thrown on the floor in an intractable state, and by the thick flooring and consequent heat at which they are subsequently worked, tendencies to lactous fermentation and mould are greatly encouraged, first in the unsound corns, and then by contact through the whole floor.

In warm weather it sometimes happens that the water becomes acescent before the grain is thoroughly swelled. This accident, which is manifest to the taste and smell, must be immediately obviated by drawing off the foul water through the tap at the bottom of the cistern, and replacing it with fresh cold water. It does no harm to renew it two or three times at one steep.

The Couch.—The water being drawn off, and occasionally a fresh quantity passed through to wash away any slimy matter which may have been generated in warm weather, the barley is now laid on the couch-floor of stone flags in square heaps, from 12 to 16 inches high, and left in that position for twenty-four hours.

At this period, the bulk of the grain being at the greatest, it is usually gauged by the revenue officers, and the quantity then found multiplied by the decimal ·815 is that on which the duty is generally charged.

After a few hours, moisture leaves the surface of the barley so completely, that it imparts no dampness to the hands; but, in from fifteen to thirty hours, sooner or later, according to the circumstances at the time of the season, quality of barley, and efficiency or otherwise of the steep, it becomes warm, the temperature rises from 7° to 10° above that of the atmosphere, while an agreeable, fruity smell is evolved; if the hand is thrust into the grain as it lies in the couch, it not only feels warm, but it is bedewed with moisture. At this sweating stage, the fibrils of the radicles make an appearance at the base of every grain, in the form of a white elevation.

After remaining in the couch twenty-four hours, the time insisted upon by excise regulation, the couch is broken, that is, the planks composing the front of it are removed, and with a maltster's wood shovel, the grain is spread out to the depth of from 6 to 10 inches (according as required by the before-mentioned circumstances; and be it remembered, that these must be carefully considered at every stage of the working, from first to last). Some few hours after the radicles have begun to divide, the plumula may be discerned at the same point, proceeding beneath the husk, to the other end of the seed, in the form of a yellow leaflet.

The Flooring.—With this last operation, 'the flooring,' may be said to have commenced, and the experience and judgment of the maltster are now called into requisition, and will be taxed to their utmost to ensure a simultaneous start and equal degree of germination in every individual grain alike; he must not forget it for a moment, but carefully watch its progress, and as soon as the grains immediately below the surface appear glossy wet from sweating, the floor must be turned with the shovel, and thinned out from 2 to 4 inches in thickness, as he sees it desirable. The manner of handling the shovel is a matter of great importance, and it is only from careful practice that the required proficiency is attained; the upper stratum of the floor is skimmed off and rolled over, just in the immediate neighbourhood of the workman, step by step, shovelful by shovelful; the under portion is then well cleaned up, flung and spread with an inward turn of the wrists, as the arms are thrown across the front; by this motion, the grains are disposed into a thin, wide-spreading shower, driven through the air and falling evenly on the floor, at a considerable distance from where they were taken up by the shovel, and by the operation are separated and cooled; should any faint smell have been attained, it will afterwards be found to have passed off in a very great measure.

Thus the workman advances, proceeding across and recrossing the floor, taking alternately, first the upper stratum, and then the lower one at every step, throwing it out the further, the more cooling or 'check' he purposes to give to it, and also regulating its area accordingly. Sometimes it requires turning over, and lightening up, without being subjected to the cooling consequent upon the use of the shovel; and for this purpose the workman uses what is called the 'rake.' This is an iron blade, about 30 inches long and perhaps 2 inches broad, fixed at each end by holders, to a massive wood head, to which is attached a strong wood shaft, with a cross-head handle. This blade is dragged along the floor, passing under the barley, turning the bottom to the top and lightening it up considerably; but when turning only is required, he uses what is called the 'plough;' this is a long-handled tool, in shape very much resembling the scull of a boat, and in using it is made to pass through the grain, precisely as a scull is made to do in the water. The young floors will generally require some sort of tendance every three or four hours; this must be judged now by the appearance of the radicle as a principal indicator; when it is particularly white and vigorous, the floor requires a 'turn,' that is, the shovel preceded by the rake; if it requires nursing, and it is thought that a turn would check it too much, the rake alone is used; but if it requires a gentle turn over and careful nursing, then the plough alone is used; and thus these are employed, either alone, in turn or combined, in any way the workman may deem it desirable; but always before leaving his house, for the night, he must thoroughly disentangle the corns, the one from the other, give the floors a good turning and spreading, thin them out, and lay them light. In the old floors it will most likely be necessary to use all three tools about them; first the plough, and then the rake, till they are well disentangled and light, then with the shovel, thin out, turn, spread, and cool them.

With the young floors, perhaps, only the plough and the rake may be required, as it sometimes happens that nursing is necessary, owing to the coldness of the weather.

It will sometimes occur, most commonly from an insufficient steep, that the radicles will show signs of withering prematurely; and if the circumstance was to remain unheeded, the floor would die long before the germination had wrought the desired change in the constitution of the barley; the withering radicles would drop off even with the most careful handling, and then the grain would have to depend on those that remained to it for the support it needed to complete the change. To render the necessary help, at this time, recourse is had to 'sprinkling,' that is, water is administered to it from a 4-gallon watering-can, with a rose, in the proportion as a rule of about one can to the quarter (8 bushels); under some circumstances a floor will take nearly double that quantity, as in the case of the heavy Scotch barleys, with only 50 hours' steep, but with light free barleys, perhaps only half the quantity, the less the better in all cases, where quality is of more consequence than appearance; for the object being to supply a stimulant to the 'fainting' and perhaps wounded grain, the acrospire is forced up as it were, under the husk of the hide-bound grain; no good, or at any rate very little good, is done by the process, to really benefit the constitution of the grain; the application is too superficial, and where the quality of the saccharine constituent is the consideration, it cannot stand in competition with the properly administered steep. But for the sake of overmeasure or overweight, and it must be admitted a saving in appearance, it is adopted by the malting-trade generally, as a matter of routine. It is administered as follows:—

On the fourth or fifth day after the grain is thrown from the cistern, the radicles will have attained the length of nearly a quarter of an inch; the floor has then given to it about half a can-full of water to the 8 bushels; it is then well ploughed, raked and turned, so as to wet every grain possible, and then worked in the usual course. Next day, the remainder of the dose is given, or if much water is thought necessary, it is given two doses the second day, one in the morning and the other in the afternoon, and perhaps another dose next morning; the operation, of course, necessitates plenty of room, so it is usual to arrange for the main sprinkling on the day that the old floors are loaded on the kilns. If floors are closely observed about this time, it will be seen, that mould mostly appears immediately after the sprinkling; then it is that the mischievous effects of rotting, mutilated, and broken corns are most apparent, and with each hour the disease spreads from corn to corn, till sometimes, before the floor can be got ready for the kiln, the whole of the floor is literally impregnated with it, a kind of blue bloom is to be perceived upon it, and it may even affect the atmosphere above it, plainly showing that mould in the form of dust is present, ready to fall on everything; some of it may be made to disappear, after drying and screening the malt; but the taste is permanently attached to the malt, and follows it through the remainder of its existence, even after it has changed its state; not that mould can be always detected in the beer made from such malt, for unless it is very bad indeed, it can be overpowered by the hop; but there is a perceptible deficiency in that fine, clean flavour, which is the perfection of a glass of good beer, its place being usurped by a flavour coarse and tangey, and tending to acidity, the more so in proportion as the disease has ravaged the malt; for let it not be forgotten, that mould and acidity always go hand-in-hand. Therefore, where it is found necessary to malt an indifferent sample of barley, it is much the wiser plan to treat it with a sufficient steep, and work it as cool as possible upon the floors, giving it plenty of time; for heats approaching 60°, and especially between 60° and 70° encourage disease in barley on the floors, just as it does also upon an unsound wort in the fermenting tin; such malts should always be set apart to be brewed by themselves for a quick consumption.

If the heat on the floor should by any chance rise to temperatures between 70° and 75°, it is almost a certainty that much of the saccharine constituent will have changed into the lactic state. It is sometimes asserted that sprinkled malt will yield more gravity per quarter than unsprinkled malt will do: the extra gravity is caused by an excess of the albuminous constituent present in the wort, and this is but an increase of trouble, disappointment, and loss to the brewer; but the difference between sprinkled and unsprinkled barley is perceived at once by the taste, being in favour of the latter, from the superior sweetness in the mouth, and it far exceeds the former in the brightening and keeping ability of its product, and in the general excellence of the beer. The attentive reader will perhaps ere this have surmised from the mention of the old floor, the young floor, and the floor to be sprinkled, that there must generally be three steeps upon the floor at the same time, and under very exceptional circumstances there may even be four floors, exclusive of those on the kiln, and in either the cistern or the couch. This of course necessitates plenty of area in the withering floor; there should be allowed 28 square yards at least to the quarter of barley steeped. Therefore for one man-kiln, 15 quarters being steeped every four days nearly, the withering-floor area should be 15 × 28 yards = 420 yards, including the couch-frame; about 30 feet in width is a nice arrangement for a kiln of this size, and is even a convenient width for any sized kiln, for where the floors are much wider, the sides and middle work vary unevenly, and cause an amount of labour that is likely to be the cause somewhat of neglect; forty feet should be the extreme limit for a kiln of the largest size; of course the wider the floor is the less throwing forward it requires, and this is a consideration; the height of the place should be about six feet under the beams, which should be underdrawn; the windows should be glazed with blue glass, and the ventilation and temperature of the place should be under complete control. At times the grain on the floors will suffer mutilation and crushing by the feet; the excise officer must trample upon it, for the purpose of gauging, but it is quite unnecessary that any one else should. Some, to relieve the floor from injury by the tread, have moveable gangways suspended from the beams above, or supported from the walls, so that the workmen can pass from floor to floor the whole length of the house without treading on the grain.

The system of working upon the floors is of such extreme importance to brewers, that it is necessary that we should give very special attention to the consideration of the several points of guidance, which experience has established as incontrovertible.

The first and most essential of these, is the selection and cleansing of the barley, and this has already been treated in detail in an early part of the present article; the next is the class and temperature of the water, and this has also been treated upon, and we must now consider the rule that must be adopted to produce a malt that shall have the least amount of the albuminous constituent in its composition along with the greatest amount of good sound saccharum as free as possible from acid tendency, and perfectly free from mould.

In the first place, in order to make good sound malt from carefully-selected barley, the efficient steep is of paramount importance; then the cooler it is worked upon the floors, and the longer it can be made to take in growing the acrospire right up to the opposite end of the grain, the better will be the saccharific excellence of the malt. The heat of the floors should never be allowed to attain 60° Fahr., and it should be kept on the floors from twelve to fifteen days, including couching.

There is no danger of mould if the turning is properly attended to, and no more sprinkling allowed than is absolutely necessary to keep the germination alive; in season-made malt, sprinkling is but very seldom required, but an exceptional warmth or dryness of the atmosphere may make it at times a necessity.

If the rootlets or radicles appear languid, shrivelled, and of a dull yellowish tint, lay the floor a little thicker; it may be that the barley is more intractable than was supposed at first; and if in the course of two or three hours its appearance is not materially improved, then administer the sprinkling, about a good third of a can-full to the quarter (i.e. 8 bushels), well plough, rake, turn, and thin out; but let it carefully be borne in mind that whatever is done in the way of increasing or decreasing the vigour of the germination must be done most gradually, or the radicles will be liable to break off, therefore leaving the grain maimed, and less able to attain the desired result, and as a consequence the quality of the malt will be impaired, On the other hand, if the rootlets appear robust and vigorous, the floor must be well turned and thinned out, or the middle of the floor will become the warmer, and an uneven germination will result; when a floor has been allowed to remain too long unturned, it may easily be perceived from the faint smell that attends it, and also it may be observed that the main or centre radicle is of unusual length and strength in comparison with its mates; great care must then be exercised, for to be checked too rapidly would certainly cause them to break off, and prove an injury; this must particularly be attended to in the young floors. If all has gone on as it should have done, when the grain has spent the moisture absorbed in the steep, the acrospire will have attained about three-fourths the length of the grain, and the culm (rootlets) somewhere about half an inch in ordinary English barley, but more than that in the strong Yorkshire barleys, and more still in the heavy Scotch; this excitation will occupy from perhaps nine to twelve days, according to the circumstances, of the kind of barley, and state of the atmosphere, and the culm will then begin to grow languid, fade, and wither, and of course will cease to develope any more; the acrospire too will remain almost stationary, though not quite so, for germination is not extinct, but only retarded. The floor must now be laid thicker, very gradually, frequently disentangled and turned, but kept just warm enough to cause most of the remaining moisture to pass away from the grain till when taken up in the hand it feels light and dry, and when the kernel is forced out from the husk with the thumb-nail, it should rub abroad between the thumb and forefinger easily and smooth; this process is called the 'mellowing,' and occupies from two and a half to four days; it is then ready for the kiln.

The Kiln-Floor.—The mellowed floor is then loaded into baskets, craned up to the kiln-floor, upset in regular heaps over it, and when all the charge is in, it should immediately be griped over and levelled. In area the kiln-floor should allow at least three square yards to every quarter of barley steeped, thus for a 15-quarter cistern, the area for the kiln-floor should be at least 45 square yards, this will allow the barley to lie from 7 to 9 inches thick upon the kiln, and that thickness is a medium between extremes. In England coke is most commonly used for the kiln-fires, and there should be from 15 to 25 feet below the centre of the kiln-floor; the greater the height the better the draught.

Immediately above the fire-place, and supported at the four corners, a disperser is placed from 6 to 9 feet above the fire-bars, according to the strength of the draught and character of malt it is intended should be made usually; it is well to have all the draught-course, both above and below the malt, under perfect control, so as to at all times cause the stream of heated air passing from the fire to disperse itself to the extreme limits of the kiln-floor; but with all the aid that art and experience can give, nothing can relieve the workman from that careful watching and regulating of the fires, that is the real secret of success in the finishing of malt. The 'old floor' being now 'loaded' on the kiln and griped over, the fire is placed and regulated so that the heat shall accumulate in the space under the floor-tiles, and fill it to the remotest corner with a temperature of about 90°, which must be the same throughout the whole area of the floor, no one place being hotter than another, or the finishing will be freckled and uneven: the advantage of having a good height over the spreader will be now seen, by reason of its allowing a better opportunity for the thorough mixture and attemperating of the atmosphere and also decreasing the liability to a hot-air current through any particular portion of the floor.

In a short time the heat may be increased three or four degrees, but the floor should not be molested till all apparent moisture or steam has been driven from it; this will take about 12 hours, when it may be griped over, again turning the top to the bottom; fires damped up and left for the night; next morning the floor must be griped again, and turned with the shovel, the fires may be broken up, and the heat increased 3 or 4 degrees more, and the floor must be turned 3 or 4 times with the shovel, and by the following morning it will most likely be dry; the finish must then be given, that is, the particular colour and flavour required must now be attained.

For pale malt, the heat should not exceed 120°.

For the amber colours, heats ranging from 120° to 160°, according to the colour desired.

For brown malt for porter-brewing, oak sticks are blazed on the fire, and the heat raised to 180° or above; the floor must not be laid more than an inch thick, and be kept constantly on the move by turning; it is therefore a very hot and laborious process. In finishing for the pale and amber malts, it is better to subject the floors to a low and long-continued heat, rather than a high and sharp one, for the culm colours much sooner than the body of the grain, owing to its slightness in substance, and the workman is often deceived by this circumstance; for pale malts, say 100° or a little above; for amber, about 125° or so.

When the malt has attained the colour required, it is immediately heaped in the middle of the kiln-floor, and the fires allowed to die down; in about two or three hours after, the kiln is 'teemed,' that is, the malt is taken off and stored in its bin: it is decidedly the best plan to let this be done while the malt is in a good hot state, for it will keep right all the longer, and the culm should go with it to aid in keeping out the atmosphere; but although malt should be kept in the store-bin as dry as possible, it is not thought a good plan to use it for brewing purposes until it has got quite cold in the heap, or it will prove somewhat intractable in the mash-tun, and the beer from it will not work kindly in the fermenting-tun, and prove somewhat difficult to fire.

During the kiln-drying, the roots and acrospire of the barley become brittle, and fall off; and are separated by a wire-sieve whose meshes are too small to allow the malt itself to pass through.

A quantity of good barley which weighs 100 pounds, being judiciously malted, will weigh, after drying and sifting, 80 pounds. Since the raw grain, dried by itself at the same temperature as the malt, would lose 12 per cent. of its weight in water, the malt process dissipates out of these remaining 88 pounds, only 8 pounds, or 8 per cent. of the raw barley. This loss consists of—

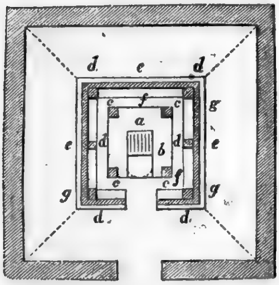
1½ per cent. dissolved out in the steep water,
3 „ dissipated in the kiln,
3 „ by the removal of the fibrils,
0½ „ of waste.

The bulk of good malt exceeds that of the barley from which it was made by about 8 or 9 per cent.

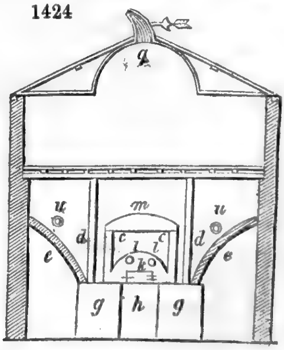
MALT KILN. (*Darre*, Ger.) The requisite conditions of a good malt kiln are, that the temperature should be under perfect control; the malt not exposed too near the direct action of the fire; and the vapour from the heated grain rapidly carried off.

Figs. 1423, 1424, 1425, 1426 exhibit the construction of a well-contrived *malt kiln*. *Fig.* 1423 is the ground plan; *fig.* 1424 is the vertical section; and *figs.* 1425 and 1426, a horizontal and vertical section in the line of the malt-plates. The same letters denote the same parts in each of the figures. A cast-iron cupola-shaped oven is supported in the middle upon a wall of brickwork four feet high; and beneath it are the grate and its ash-pit. The smoke passes off through two equidistant pipes into the chimney. The oven is surrounded with four pillars, on whose top a stone lintel

1423

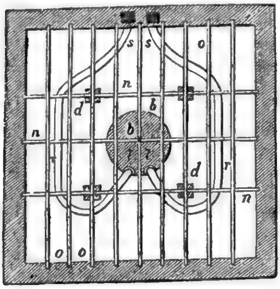


1424

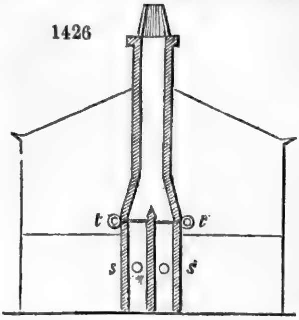


is laid: *a* is the grate, 9 inches below the sole of the oven *b*; *c c c c* are the four nine-inch strong pillars of brickwork which bear the lintel *m*; *d d d d* are strong nine-inch pillars, which support the girder and joists upon which perforated plates repose; *e* denotes a vaulted arch on each of the four sides of the oven; *f* is the space between the kiln and the side arch, into which a workman may enter to inspect and clean the kiln; *g g*, the walls on either side of the kiln, upon which the arches rest; *h*, the space for the ashes to fall; *k*, the fire-door of the kiln; *l l*, junction-pieces to connect the pipes *r r* with the kiln; the mode of attaching them is shown in *fig.* 1425. These smoke-pipes lie about three feet under the iron plates, and at the same distance from the side walls; they are supported upon iron props, which are made fast to the arches. In *fig.* 1424, *u* shows their section; at *s s*, *fig.* 1425, they enter the chimney, which is provided with two register or damper plates, to regulate the draught through the pipes. These registers are represented by *t t*, *fig.* 1426, which shows a perpendicular section of the chimney. *m*, *fig.* 1424, is the lintel, which causes the heated air to spread laterally, instead of ascending in one mass in the middle, and prevents any combustible particles from falling upon the iron cupola. *n n* are the main girders of iron for the iron beams *o o*, upon which the perforated plates *p* lie; *q*, *fig.* 1424, is the vapour-pipe in the middle of the roof, which allows the steam of the drying malt to escape. The kiln may be heated either with coal or wood.

1425



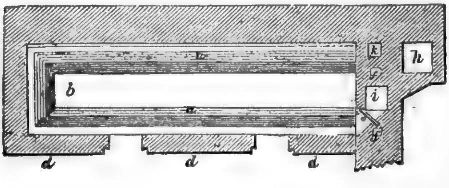
1426



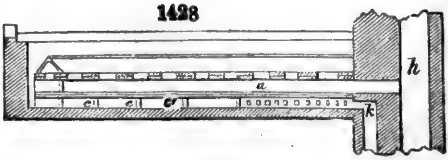
The size of this kiln is about 20 feet square; but it may be made proportionally either smaller or greater. The perforated floor should be large enough to receive the contents of one steep or couch.

The perforated plate might be conveniently heated by steam-pipes, laid zigzag, or in parallel lines under it; or a wire-gauze web might be stretched upon such pipes. The wooden joists of a common floor would answer perfectly to support this steam-range, and the heat of the pipes would cause an abundant circulation of air. For drying the pale malt of the ale-brewer, this plan is particularly well adapted.

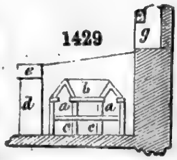
1427



1428



1429



The improved malt kiln of Pistorin is represented, *fig.* 1427, in a top view; *fig.* 1428, in a longitudinal view and section; and *fig.* 1429, in transverse section. *a*, *a*, are two quadrangular smoke-flues, constructed of fire-tiles, or fire-stones, and covered with iron plates, over which a pent-house roof is laid; the whole bound by the cross pieces *b* (*figs.* 1428, 1429). These flues are built above a grating *c c*, which commences at *c′*; in front of *c′* there is a bridge of bricks. Instead of such a brick flue covered with plates, iron pipes may be used, covered with semi-cylindrical tiles, to prevent the malt that may happen to fall from being burned. *d d*, are the breast walls of the kiln, 3 feet high, furnished with two apertures shut with iron doors, through which the malt that drops down may be removed from time to time. *e* is a beam of wood lying on the breast wall, against which the hurdles are laid down slantingly towards the back wall of the kiln; *f f* are two vertical flues left in the substance of the walls, through which the hot air, discharged by open pipes laid in a subjacent furnace, rises into the space between the pent-house roof and the iron plates, and is thence allowed to issue through apertures in the sides. *g* is the discharge-flue in the back wall of the kiln for the air now saturated with moisture; *h* is a smoke-pipe, from which the smoke passes into the anterior flue *a*, provided with a side-plate for modifying the draught; the smoke thence flows off through a flue, fitted also with a damper-plate, into the chimney *i*. *k* is a smoke-pipe of a subsidiary fire, in case no smoke should pass through *h*. The iron pipes are 11 inches in diameter; the air-flues *f*, 5 inches, and the smoke-pipe *h*, 10 inches square; the brick flues 10 inches wide, and the usual height of bricks.

The following is an account of the total number of bushels of malt made in the United Kingdom from 1861 to 1870, distinguishing such as were charged with duty from such as were free of duty, exported on drawback or free of duty, and the quantities returned for home consumption:—

The Quantities of Malt charged with duties of Excise in the United Kingdom, quantities exported on drawback, and returned for home consumption.

Years	Charged with duty	Free of duty[1]	Exported on drawback or free of duty[2]	Retained for home consumption
	Bushels	Bushels	Bushels	Bushels
1861 . . .	44,141,422	3,793,192	1,284,514	46,650,100
1862 . . .	41,118,172	4,069,883	1,499,447	43,688,608
1863 . . .	46,269,842	4,679,829	1,876,856	49,072,815
1864 . . .	48,544,125	4,837,742	1,584,889	51,796,998
1865 . . .	45,190,374	522,828	1,641,685	43,548,689
1866 . . .	45,982,397	551,423	1,687,344	44,295,053
1867 . . .	43,608,571	459,660	1,385,577	42,222,994
1868 . . .	44,387,259	452,880	1,330,664	43,056,595
1869 . . .	45,351,518	484,907	1,537,147	43,814,371
1870[3] . . .	47,005,803	402,455	1,462,226	45,603,577

MALVACEÆ. The petals of the plant known as *Althæa rosea*, belonging to the natural order *Malvaceæ*, contain a peculiar colouring-matter, soluble in water and alcohol, but insoluble in ether. ‘The aqueous solutions of the petals, freed previously from the calyx and stamens, exhibit a violet-red colour, which is turned crimson by the addition of acids and green by alkalis. The alcoholic tincture of the leaves is purplish-red, and leaves on evaporation a deep red residue, free from nitrogenous matter. Cotton mordanted with iron is turned blue or bluish-black by an aqueous infusion of the petals. With an aluminous mordant a violet-blue, and with tin mordants a bluish-violet is produced. Woollen fabrics, previously mordanted with bichloride of tin, assume a deep violet, and when mordanted with iron a bluish-black or grey; if mordanted with antimonic-acid salts, a bluish-violet is obtained; silk mordanted with tin salts takes a violet.

‘For calico-printing purposes the alcoholic extract suits better than the aqueous infusion. The colours produced are faster than those yielded by logwood, but they do not stand clearing with soap.

‘The colouring matter is yet, and was formerly far more so, in great request for the artificial colouration of wines. Latterly it has come into use as a dye-ware, and is chiefly so applied in Germany and more particularly in Bavaria.’

MAMMEE. A tree growing in Honduras. Its dried leaves are very powerfully narcotic; the bark is, however, stated to possess some tonic properties. The flowers of the tree are used in flavouring a *liqueur* made in some parts of the West Indies, called *crême des créolès.—Temple.*

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[1] Including the estimated quantity used in beer exported.

[2] On the 14th of August 1855, malt was made free of duty for distillery purposes and for exportation, and spirits were allowed to be distilled free of duty for exportation.

[3] The Board of Trade has not published any later return.

MANCHESTER YELLOW. A name by which naphthaline yellow is known in commerce.

MANCHINEEL. A large tree of a very poisonous character, growing in South America, and in some parts of the West Indies. The wood is of a yellow-brown colour, beautifully clouded, and very close and hard. It is sometimes used instead of mahogany. This tree is the *Hippomane mancinella*, one of the *Euphorbiaceæ*

MANDIOCA. Cassava starch. See STARCH.

MAN-ENGINE. (*Machine d'Ascension*, Fr.; *Fahrkunst*, Ger.) The name given to a machine by which the men working in deep metalliferous mines are enabled to descend or ascend without much fatigue. The labour of climbing from the bottom of the deep mines of the Hartz and of Cornwall has long been known to produce an injurious effect upon the men. It has therefore long been deemed of the utmost importance to devise some means by which relief might be afforded.

It was not till 1833 that the circumstance of two water-wheels having been thrown out of work by the opening of the deep George adit in the Hartz mines suggested the idea of employing the pump-rods for aiding the ascent of the miners, and in such manner that every man should, as on the simple ladder plan, depend on himself alone for his safety; the ascent to be effected by means of the water-wheels' power. There was sufficient room in the shaft, which was perpendicular, and an experiment of 100 fathoms was set in operation. The rods were entirely of wood, of a very simple and solid construction. The spars were cut 4 × 6, and joggled into each other one inch, and bolted together, so that the whole was 7 × 6; at the joints iron plates 20 inches long were put on and screwed together, so as to render the whole equally strong; tearing asunder, as long as the timber remains sound, being nearly impossible. The whole length was then divided into 22 stages, and from the top downwards, on alternate sides for each stage, the steps were fastened, at distances of 4 feet, by iron rests. In like manner, hand-holds were fastened at convenient distances. Between the two rods ordinary ladders were placed against one side of the shaft, for the sake of safety should anyone become confused, or should the machinery from any accident stand still. On a given signal, the machine was set in motion by the man at the engine, who regulates the supply of water according to the number of men on at a time. This number was not allowed to exceed 20 men for this machine (except in cases of necessity) although of sufficient strength to support a much greater number.

The perpendicular rods were supported at every stage by rollers, which were always placed where there is no step. They were of fir, 10 inches long, 12 inches in diameter, and a cast-iron flange of 1½ inch fastened to them at each end, to prevent the rods slipping off; at five different points it was so arranged that the rods could not fall farther than to the next stage, or at the utmost 48 inches, that being the length of stroke. The ascent on the machine requires no description; the miners, after the second trial, felt familiar with it, nor was there any more danger than if they were on the ordinary ladder. This machine, or *power-ladder*, was calculated to ease the toil of ascent; but it has also been used in descending, when of course it requires little or no water to set it in motion; and in cases of want of water, the descending miners might bring up the men who had finished their shift, the water-wheel only regulating the motion and overcoming friction and other prejudicial resistances. This first machine surpassed expectation; short as the length of ascent was, many invalids of the district found new sources of employment, and the descent by this was used by many, especially during winter, who could reach far-removed mines by underground communication. Gradually the most prejudiced were attracted to the machine, and it is received as a blessing. Thoroughly convinced of the excellence of the contrivance, 200 fathoms of the 340 fathoms of Duke George William shaft, from grass downwards, were in 1838 provided with a power-ladder similar in construction to the above described, with this difference only, that this being on the vein which falls at an angle of 70°, only certain distances of 5, 8, 12 fathoms are taken on the machine, and intermediate of 5 to 10 fathoms on the usual ladders, which divides the strain on the machine, provides against catching colds, and in some degree against the danger of falling. Thus one of the deepest shafts was rendered easy of ascent, more than half the depth being furnished with power for raising the miners.

In 1836 another machine was completed in the Schreibfeder Schacht. Here the machine-rods must also serve as *pump-rods* in time of flood, and therefore the notion of making the rods of iron wire, thrown out by Albert, could not be brought to bear, but a combination of timber and iron wire was adopted. The rods were of the best spars joggled, as in the former cases; but in the two grooves run in these there were let in two iron-wire ropes of 12 wires each. The two spars were screwed tight upon the ropes, which were steeped in prepared tar. Thus the ropes formed a core to the wooden rods, which in themselves were sufficiently strong for the strain, but the ropes were a protection, should the wood decay, against any misfortune, while the wood gave sufficient stiffness to the rope-rod. These rods were not above half the weight of the former per fathom.

It was very fairly objected to this construction, that it was uncertain what strain came on the wood, what on the iron, and that damage on the iron wire could not be observed. 124 fathoms of the 265 were provided with a power-ladder of this construction. The ascent on it is not continuous, but alternating, as in the Duke George William shaft, so that of $143\frac{5}{8}$ fathoms, $124\frac{1}{2}$ are by the machine, $19\frac{1}{8}$ on the fixed ladders.

These being accomplished, several experiments were begun in 1836 to endeavour to arrive at a construction of rod, at once lighter and mechanically more perfect. First, a wire-rope ladder, as it were, laid along planks as a continuous bearing, and having here and there rollers, so attached as to keep the rope down on the planks, was tried. Steps and hand-holds were made fast to the rope, so that no injury resulted to the rope. The necessary stiffness was wanting, the small rollers were insufficient, and the planks were very rapidly worn. Second, a wire rod, as it were, of four ropes in a square, nine wires in a rope, with inch boards on one side running on fixed rollers. The four ropes made a parallelogram of 6 and 7 inches, between which hand-holds and steps were fastened. The boards were protected by iron friction-pieces, where they ran on the rollers; ten fathoms weighed 42·9 lbs., and cost about one hundred thalers. The only objection to this was, that the four ropes could not be depended upon as being equally strained. Third, Albert's proposal to have two ropes of the wire parallel to each other, 2-inch and 10-inch deals to be attached to the back of these, without any other connection: to let these run as usual on rollers, and fastening the steps and hand-holds to the ropes. It was tried in Duke George William's shaft, and found the most noiseless and easiest in go, and on the whole, most perfectly fulfilling the required conditions. This construction, with some modifications by M. Jordan, was finally determined upon, and has since been carried out in the Samson shaft, in Andreasberg, 345 fathoms deep, and now to be particularly described.

In this case there was the advantage and disadvantage of having to provide everything for the express purpose of the ascending machine. A new wheel-room had to be executed, new watercourses to be driven, new wheels to be built;—an advantage, so far as the whole was perfectly adapted to the end in view; a disadvantage, inasmuch as the expense was very greatly increased. The fact, however, proves the importance attached to the means of facilitating the miner's operations. Any further mention of the arrangements for the necessary power, than that the mover is water and the machine an ordinary water-wheel, over-shot, 42 feet in diameter, 4 feet on the breast, making from two to two and a half revolutions per minute, is unnecessary. The letting-on of the water is regulated from the top of the shaft, where there is a miniature machine moved by rods and gear, connected with the power-ladder, indicating exactly the relative position of everything below ground. A system of signals, too, has been adopted, by which most of the circumstances occurring in connection with the working of the ladder can be immediately made known above ground. The *Spannschütze*, a sluice or pen-trough of admirable construction, is applied to this wheel, as its load is very variable. The crank is 3 × 6 feet long, of cast iron, and is attached by a connecting rod with framed rods that work the crosses at the shaft head in the usual manner.

The method of hanging the ladders deserves attention, as it is perfectly successful and very simple. In the history of the machines there have been several arrangements tried, but this is the last and considered the best. The power-ladders are hung on the cross-head of a knife-edge by two iron slings, 6 × 2 inches. They were in this ladder first hung by passing the ropes round a segmental frame, but the friction of the knife-edge induced a continual bending of the rope; through a very small angle, it is true, but such, that under its effects the wires gave way at the end of three months. This led to an arrangement by which the ropes are bound between timbers bolted and screwed together, and thus the whole hung to the things above-mentioned.

Perhaps the most efficient construction would be the passing the ropes round an arched head, as was the connection between the beam of the steam-engine and piston-rod of old, only passing the ropes over a greater segment than was or is customary.

The ropes at the top consist of 36 wires, viz., three ropes of 12 wires in each rope, and these together cable laid. In the timbers, grooves are cut of such dimensions that the screw bolts may have the effect of so pressing the timbers together, that the ropes are held in place by the friction thus induced. The length of these timbers is 4½ fathoms; this great length is a consequence of local circumstances.

The rope diminishes gradually, viz., four wires less for each 50 fathoms descent. The estimate of the strength required was made thus:—

	lbs.
1. The weight of the rope	5,600
2. Weight of steps and handles, &c.	2,200
3. Weight of 50 men	7,500
4. 185 fathoms of deal and 90 fathoms slide-bar . .	6,795
	22,095

And assuming that the double rope of 36 wires would bear, at the utmost, $2 \times 36 \times 1{,}100$ lbs. $= 79{,}200$ lbs., the load of 22,095 lbs. would be 28 per cent. of the ultimate strength.

For safety in case of the accident of the power-ladder breaking, several good arrangements have been adopted, so that any serious accident is not likely to occur, should even a side of the power-ladder give way. At several parts of the length, the two sides of the ladder are connected together by a very strong chain; this chain passes over a fixed pulley; and it is evident that, if on either side the ladder were to break above this, its fall, if not entirely checked, would be very much broken by the counterbalancing weight of the other side, acting by means of the chain.

Again, at various stages there are wedge-shaped blocks attached to the planks, in which are fixed the friction pieces, and these wedges would fall into wedge-shaped bearings, that are secured by timbering in the shaft, and so, having broken at any point above these, the fall is limited to 7 feet at the utmost.

In conclusion, it may be mentioned that in order to ascertain the exact state of the wires, several pieces of the rope have been kept exposed in different parts of the shaft; these are from time to time examined, but since 1837, when the power-ladder of iron wire was erected in Andreasberg, the progress has been so very slow, that little is to be apprehended from the effects of rust, so long as care is taken to keep the ropes properly tarred.

The total cost of one side was 607 Prussian thalers, and therefore the total cost of power-ladder was 1,214 thalers = 182*l.* 10*s.*

The mines in Cornwall being as deep as those in the Hartz, it became a question of moment to adopt some machine for the relief of the miner in that county. Medical men had long expressed their conviction that much of the lung disease prevalent amongst the men working in the deep mines of the Gwennap district was due to the violent exertion of climbing on perpendicular ladders from a depth varying from 200 to upwards of 300 fathoms. At length the subject was taken up by the Royal Cornwall Polytechnic Society, and a man-engine was introduced, which in most respects resembled the German power-ladders.

The following is a short account of the principal phases of its introduction, due entirely to the ready and generous initiative taken by the Polytechnic Society:—

At the first general meeting of the society in 1834 Mr. Charles Fox offered three prizes for the perfection of the means then in use for the descent and the ascension of miners. The first project was that of Michael Loam the engineer, the same who afterwards constructed the machine at Tresavean. The competition remained open for many years; several plans were produced, and the prizes awarded. In 1838 Mr. Fox offered 100*l.* to the first mine that would make a trial in the desired way; this example was followed by other individuals, and the sum of 530*l.* was put into the hands of a committee, who were charged with sending circulars to the mines. The adventurers of Tresavean accepted the proposed conditions, and in January 1842, two rods moving alternately, conducted by an hydraulic wheel, were working to a depth of 26 fathoms. The steps were 12 feet distant from each other, and each rod moved 6 feet; so that the men changed their position at each step. By the advice of Mr. Loam, it was decided to substitute a steam-engine for the hydraulic wheel, so that the motive power could not fail, and at the same time it was judged advisable to increase the stroke of the rods 12 feet; the number of the steps and the distance between them remaining the same, so that the men had only to change at every other one, and the same number of miners could ascend and descend at once.

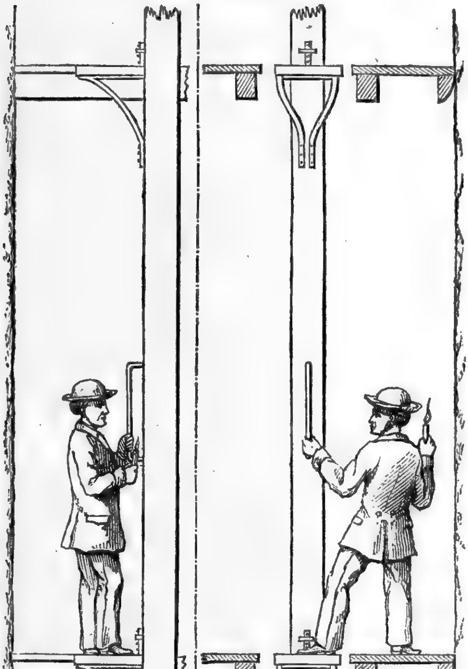
On October 25, 1842, the machine, thus modified, had attained to the depth of 140 fathoms, and on June 20, 1843, it was finished; its length being 290 fathoms, and the mine being at this time 311 fathoms deep below the adit.

The second man-engine was constructed by Hocking and Loam, in 1845, at the Great United Mines in Gwennap. The temperature was 120° Fahr. at the bottom of the mine, and it was an urgent necessity to diminish the fatigue of the miners as much as possible. They contented themselves with copying the plan which had succeeded so well at Trevesean, only making some slight differences in detail.

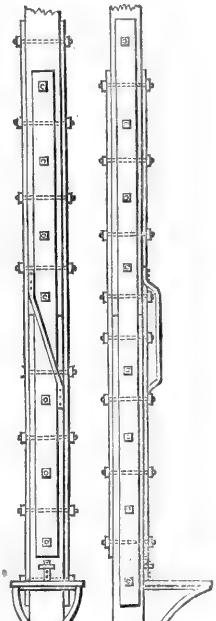
In 1851 the late Captain Puckey and Mr. West, an engineer, adopted a new system for the Fowey Consols mine.

A single rod, furnished with steps, worked in the shaft; a series of platforms are fixed at different parts of the shaft; these have, like the steps, spaces of 12 feet between them, and they are placed on a level corresponding with the steps at the extremity of the stroke of the rod. The miner, quitting one step, waits on the platform until the next reaches him. This man-engine can also be used at the same time by miners ascending and by miners descending. The stoppage at the platform is of sufficient length for one man to pass on to the step which another has just abandoned.

1430



1431



The machine with a single rod has been since applied by Mr. Hocking to Levant mine, and in 1854 to that of Dolcoath. It may thus be considered as being now the most used in Cornwall, and it possesses an incontestable superiority over machines with two rods.

The man-engines in the Cornish mines are so much alike in their construction, that it is quite unnecessary to describe each of them. Their general characters will be understood by examining the accompanying woodcuts, *figs.* 1430 and 1431.

At Fowey Consols the machine is worked by a water-wheel of about 50 horse-power, but all the other man-engines are worked by the ordinary Cornish steam-engine, that is, with a cylinder vertical and balanced; and always double-acting. The outer end of the beam of the machine is attached by a sweep-rod to two small wheels which are situated on the shaft; these drive two larger wheels, so that the engine makes several strokes to one revolution of the wheels. In some of the mines the engine, besides giving motion to the man-engine, is used for crushing the ores and performing other work, while in others it is merely employed for raising and lowering the miners. The rods are generally about 7 or 8 inches square, slightly decreasing in size as they descend. When there are two rods the steps are so placed that there is a distance of about 6 inches between them when the man passes from one to the other. The weight of the rod is counterbalanced sometimes by levers and sometimes by balance-bobs attached to it in different levels. The greatest object gained in the use of levers is a considerable saving in expense, both in the materials of which they are made, and in the size of the piece of ground that must be excavated to receive the balance-bobs. There are twelve feet of space between the step on the rod, and 4 feet above each step are round bars of iron fixed vertically into the rod, to serve as hand-holds, and maintain the miner in his position on the step with perfect safety. In case of accident happening to any part of the machinery, there are catches placed at every few fathoms, so that the fall cannot be great.

The man-engine with a single rod is generally used in Cornwall, because it possesses so many advantages over that with two: the expense of erection is much less, it enables the miner to mount and descend in as short a space of time, and the number who can do so per minute is doubled; the work performed by the machine is also increased. There are signals connected with the man-engine, by which the miner can communicate with the surface from every platform.

The usual speed of the engine is 15 strokes per minute, by which each rod makes 3 strokes during that time. Therefore, the rate at which it travels is 12 fathoms per minute ascending and descending: this speed enables a miner to travel in 24 minutes a space that he would otherwise take 60 minutes to perform. In case of any accident happening to the man-engine, there are always ladders placed by the side of it; sometimes they only go from platform to platform; in other mines there are bars nailed on the rod, so that the miner can climb on them until he regains the principal ladders.

The man-engine possesses almost innumerable advantages over the ladders; the greatest is the immense saving of fatigue to the miner. When there are only ladders in a mine, he sometimes takes an hour or more to reach the place where he is working, and then only with immense bodily exertion; on a man-engine he can reach the same place in about a third of the time, and as free from fatigue and ready for hard work as when he started from the surface. Even those who have never been in a mine cannot but appreciate the great blessing this simple invention is to the miners, if they have only seen the exhausted state in which they reach the surface after having ascended by ladders from any great depth. At first it was feared the man-engine might be dangerous, that the speed at which it worked would not allow time for the men to step from one platform to another, but after one or two trials it was found that no fears need be entertained on that account, and it was pronounced by the miners as perfectly safe as ladders.

In 1845 M. Warocqué constructed similar machines in Belgium. These have been described in the *Revue Scientifique et Industrielle*, under the several denominations of 'Fahrkunst,' 'Man-Engine,' 'Warocquière,' 'Machine d'Ascension,' and 'Échelles Mobiles.' The first application was made, as we have already said, by M. Warocqué at the pit of St. Nicholas, belonging to the colliery of Mariemont, to a depth of 220 mètres—about 240 yards. A full account of these machines will be found in the *Annales des Travaux publics*, tome v., p. 79, by M. Delvaux de Fenffe; in the *Traité d'Exploitation* by M. Combes; *Notice sur les Appareils de Translation des Mineurs dans les Puits*, by M. A. De Vaux; also in the *Annales des Travaux publics de Belgique*; and by M. Moissenet in the *Annales des Mines*.

MANGANATES; PERMANGANATES; CONDY'S FLUID. Dr. Hofmann, in his report on the chemical products of the Exhibition of 1862, has the following excellent remarks on *soluble saline oxidising disinfectants*. Of this variety of oxidising disinfectants the alkaline manganates and permanganates are the best examples; and in this cursory sketch, attention may be confined to these as types of their class.

Alkaline Manganates and Permanganates.—Chemists have long known and turned to account, in laboratory operations, the powerful oxidising action of the salts of permanganic acid. The rapidity and definiteness of their action, and the marked change of colour by which their loss of oxygen is attended, renders these compounds invaluable as instruments of analytical researches. And the same properties, coupled with their perfectly innocuous character, adapts them admirably for disinfecting purposes. Their action is certainly superior to that of chloride of lime and alkaline hypochlorites; for although these are also oxidising disinfectants, they act indirectly by decomposing water, from which the chlorine takes hydrogen to form hydrochloric acid, thus liberating oxygen for the supply of the putrefying matter. The manganates and permanganates, on the contrary, are agents of direct oxidation, yielding up, as they do, part of their own oxygen to the combustible elements of putrescible compounds. The manganates thus supply one-fourth, the permanganates no less than three-eighths, of the oxygen they respectively contain, peroxide of manganese being in both cases precipitated, and the alkaline base remaining in solution in the form of carbonate.

Their Efficacy as Disinfectants.—Dr. Hofmann has had many opportunities of satisfying himself of their efficacy as disinfectants. Waters taken from stagnating ponds highly charged with organic matter in a state of most active putrefaction, and emitting the most repulsive odour, were instantaneously deodorised by a comparatively small quantity of permanganate, or even manganate of potassium or sodium. After the brown precipitate of peroxide of manganese had been allowed to subside, the waters examined by Dr. Hofmann had become perfectly clear and colourless, having permanently lost their offensive smell and taste. The taint of some of these waters had survived the action of even very considerable quantities of the usually-applied metallic salts. Their deodorisation by chloride of lime was likewise rapid and permanent; but, though entirely deprived of their original putrid odour, the chlorine-treated waters retained a faint, peculiar smell, probably due to the chloride of nitrogen, generated by the action of free chlorine upon their ammoniacal constituents.

For freeing river or other waters from ammoniacal impregnations, the disappearance of the colours of the manganates and permanganates, in proportion as their oxidising action goes on, particularly adapts them. By the fading of the colour (emerald, if manganate is used; purple, if permanganate) the operator can follow the process of oxidation, and graduate his additions with the utmost accuracy. By careful manipulation he may completely free the water from organic impurity, introducing into it, in exchange, only a minute quantity of an alkaline carbonate. This is rarely an objectionable, frequently rather a serviceable, addition; especially in the case of hard waters, which are thus softened.

Their minor applications.—The innocuous character of these substances has already been referred to; and it is not the least valuable of their properties. It permits of their being used for a variety of purposes to which disinfectants have hitherto been almost entirely inapplicable. Among them are some of great value, such as disinfection of all parts of the living animal body (deodorisation of the breath, disinfection of ulcers, wounds, &c.). Scarcely less important is the service they are capable of rendering to the vegetable organism when suffering from blight and similar pernicious influences. They may also be advantageously employed for the purification of tainted provisions, &c. It may be of some interest to the smokers of tobacco to know that by rinsing out the mouth with a dilute solution of permanganate of sodium every trace of the odour of tobacco is almost instantaneously got rid of. Among the numerous applications of minor importance which Mr. Condy suggests for the manganic disinfectants is their use by wine-tasters for refreshing their palates when engaged in the important duties of their profession. They are also said to subdue the irritation caused by the bites of gnats and other still more disagreeable insects.

The manganic disinfectants are thus seen to possess a combination of properties which in many cases may render their application preferable to that of the hypochlorites. These latter, however, have the superiority as atmospheric disinfectants, on account of their exhalation of chlorine gas, in a more or less dilute state, when acted on by acids, or acid salts, or even by the atmosphere itself. This property of chloride of lime will always secure it a field of application, in which it is not likely to be superseded by non-volatile disinfectants of any kind.

Their Manufacture.—It only now remains to say a few words concerning the manufacture of the alkaline manganates and permanganates, which is accomplished by a very simple and easy process.

For laboratory purposes the potassic permanganates are usually preferred to the corresponding sodic compound, on account of the superior crystallising properties of the former salt, and the facilities thus afforded for its purification. For industrial purposes, on the other hand, where cheapness is far more important than perfect purity, the manganate and permanganate of sodium are always used. Mr. Condy manufactures manganates of sodium simply by mixing caustic soda with finely-divided peroxide of manganese, and exposing the mixture in shallow vessels, for

48 hours, to a dull red heat. The proportions employed by Mr. Condy are 1½ ton of soda-ash, caustified in the usual way, to 7 cwts. of peroxide of manganese. The product of the reaction is treated with a sufficient quantity of water to convert (partly, at all events) the manganate into permanganate; and the solution is evaporated to an appropriate state of concentration or to dryness. In some cases Mr. Condy transforms the manganate into the permanganate by the addition of sulphuric acid. On evaporating the solution thus formed, crystals of sulphate of sodium separate; these are fished out, and the liquid is ultimately boiled down to dryness. See DISINFECTANTS.

MANGANESE (Eng. and Fr.; *Mangan, Braunsteinmetall,* Ger.) is a greyish-white metal, of a fine-grained fracture, very hard, very brittle, with considerable lustre, of specific gravity 8·013, and requiring for fusion an extreme heat. It should be kept in closely-stoppered bottles, under naphtha, like potassium, because with contact of air it speedily gets oxidised, and falls into powder. It decomposes water slowly at common temperatures, and rapidly at a red heat. Pure oxide of manganese can be reduced to the metallic state only in small quantities, by mixing it with lamp-black and oil into a dough, and exposing the mixture to the intense heat of a smith's forge, in a luted crucible; which must be shaken occasionally to favour the agglomeration of the particles into a button. Thus procured, it contains, however, a little carbon. Some improvements in the reduction of manganese have recently been effected by Mr. Hugo Tamm.

Manganese is supposed to perform an important part in the compound of iron, known as *Spiegeleisen,* which is now so largely employed in the manufacture of the Bessemer Steel. See SPIEGELEISEN and STEEL.

MANGANESE, ORES OF. There are two principal ores of this metal, which occur in great masses; the peroxide, and the hydrated oxide; but all the ores of manganese are described in the following paragraphs:—

Pyrolusite, or grey manganese ore, has a metallic lustre, a steel-grey colour, and affords a black powder. Specific gravity 4·85. Scratches calc-spar. It effervesces briskly with borax at the blowpipe, in consequence of the disengagement of oxygen gas. This is the most common ore of manganese, and a very valuable one, being the substance mostly employed in the manufacture of chloride of lime and of flint glass. It is the peroxide. It contains manganese, 63·3; oxygen, 36·7. Great quantities are found near Tavistock in Devonshire and Launceston in Cornwall.

Braunite is a dark brown substance of glassy metallic lustre, affording a brown powder. Specific gravity 4·8. It scratches felspar, but is scratched by quartz. Infusible at the blowpipe, and effervesces but slightly when fused with glass of borax. It is the sesquioxide, containing manganese, 69·68; oxygen, 30·32. It gives out at a red heat only 3 per cent. of oxygen. *Hausmannite* is a rarer ore, consisting of the protoxide and sesquioxide of manganese.

Manganite is brownish-black or iron-black, powder brown, with somewhat of a metallic lustre. Specific gravity 4·3. Scratches fluor-spar. Affords water by calcination in a glass tube; infusible at the blowpipe; and effervesces slightly when fused with glass of borax. It consists of manganese, 62·68; oxygen, 27·22; water, 10·10; and is therefore a hydrated sesquioxide.

Manganese-blende, or sulphide of manganese, has a metallic aspect; is black or dark steel-grey. Specific gravity 3·95. Has no cleavage; cannot be cut. Infusible, but affords, after being roasted, distinct evidence of manganese by giving a violet tinge to soda at the blowpipe. Soluble in nitric acid; solution yields a white precipitate, with the ferrocyanide of potassium. It consists of sulphur, 37·90; manganese, 62·10.

Diallogite; Carbonate of Manganese. Specific gravity 3·4. Affords a green frit by fusion with carbonate of soda; is soluble, with some effervescence, in nitric acid; solution, when freed from iron by succinate of ammonia, gives a white precipitate, with ferrocyanide of potassium. Carbonic acid, 38·20; protoxide of manganese, 61·80.

Rhodonite, or *Hydrosilicate of Manganese,* is a brownish-red-looking substance, which yields a yellowish-brown powder, and water by calcination; is acted on by muriatic acid, but affords no chlorine. It consists of silica, 45; protoxide of manganese, 54·1.

Wad, or *Bog Manganese,* is the old English name of the hydrated peroxide of manganese. It occurs in various imitative shapes, in froth-like coatings upon other minerals, as also massive. Some varieties possess imperfect metallic lustre. The external colour is a dark brown of various shades, and similar in the streak, only shining. It is opaque, very sectile, soils and writes. Its specific gravity is about 3·7. Mixed with linseed-oil into a dough, black wad forms a mass that spontaneously inflames. The localities of wad are particularly Cornwall and Devonshire, the Hartz, and Piedmont. Wad from Devonshire gave—oxide of manganese, 79·12; oxygen, 8·82; water, 10·06.

The manufacturer of flint glass uses a small proportion of the black manganese ore, to correct the green tinge which his glass is apt to derive from the iron present in the sand he employs. To him it is of great consequence to get a native manganese containing as little iron oxide as possible; since, in fact, the colour or limpidity of his product will depend altogether upon that circumstance. See GLASS.

The peroxide of manganese is used also in the formation of glass-pastes, and in making the black enamel of pottery.

The restoration of manganese to the state of peroxide, for the chemical arts in which it is so extensively consumed, has been long a desideratum in manufactures.

The chief use of 'manganese' (binoxide of manganese) is in the manufacture of chlorine for bleaching-powder. The spent manganese may now be regenerated by Mr. Walter Weldon's process. See CHLORINE.

Sulphate of manganese has of late years been introduced into calico-printing, to give a chocolate or bronze impression. It is easily formed by heating the black oxide, mixed with a little ground coal, with sulphuric acid. See CALICO-PRINTING.

For some of the other uses of manganese in the arts, see BLEACHING and CHLOROMETRY.

For a simple method of ascertaining the value of this substance in the production of chlorine, and the manufacture of the chlorides and chlorates, see CHLOROMETRY.

Imports of manganese in 1869–72, and 1873:—

	1869		1870		1872		1873	
	Tons	Computed real value	Tons	Computed real value	Tons	Computed real value	Tons	Computed real value
		£		£		£		£
From Holland . .	8,793	30,776	6,753	28,702	5,400	24,693	913	4,689
,, Portugal . .	10,445	52,225	9,296	46,480	12,569	75,650	6,492	39,090
,, Spain . . .	27,667	138,335	13,329	66,645	19,502	114,215	16,025	92,047
,, Greece . . .	..	..	..	..	..	..	950	5,700
,, other parts . .	4,612	15,556	3,325	15,232	1,373	8,672	1,397	9,457
Total . .	51,517	236,892	32,703	154,059	38,934	223,230	25,777	150,983

MANGANESE, OXIDES OF. Manganese is susceptible of five degrees of oxygenation:—

1. The *Protoxide* may be obtained from a solution of the sulphate by precipitation with carbonate of potash, and expelling the carbonic acid from the washed and dried carbonate, by calcination in a close vessel filled with hydrogen gas, taking care that no air have access during the cooling. It is a pale-green powder, which slowly attracts oxygen from the air, and becomes brown; on which account it should be kept in glass tubes containing hydrogen, and hermetically sealed. It consists of metal, 77·57; oxygen, 22·43. It forms, with 24 per cent. of water, a white hydrate; and with acids, saline compounds, which are white, pink, or amethyst coloured. They have a bitter acerb taste, and afford with hydrogenated sulphide of ammonia a flesh-red precipitate, but with caustic alkalis one which soon turns brown-red, and eventually black.

2. The *Sesquioxide of Manganese* exists native in the mineral called *Braunite*; but it may be procured either by calcining at a red heat the proto-nitrate, or by spontaneous oxidisement of the protoxide in the air. It is black; when finely pulverised, dark brown; and is convertible, on being heated in acids, into protoxide, with disengagement of oxygen gas. It consists of metal, 69·75; oxygen, 30·25. It forms with 10 per cent. of water, a liver-brown hydrate, which occurs native under the name of *Manganite*. It dissolves readily in tartaric and citric acids, but in few others. This oxide constitutes a bronze ground in calico-printing.

3. *Peroxide of Manganese*, or *Pyrolusite*, occurs abundantly in nature. It gives out oxygen freely when heated, and becomes an oxidulated deutoxide. It consists of metal, 63·36; oxygen, 36·64.

4. *Manganic Acid* forms green-coloured salts, but has not hitherto been insulated from the bases. It consists of metal, 53·55; oxygen, 46·45.

5. *Hypermanganic Acid* consists of metal, 49·70; oxygen, 50·30. See Watts's 'Dictionary of Chemistry.'

MANGLE. (*Calandre*, Fr.; *Mangel*, Ger.) This is a well-known machine for smoothing linen and cotton furniture. As usually made, it consists of an oblong, rectangular wooden chest, filled with stones, which load it to a degree of pressure that it should exercise upon the two cylinders on which it rests, and which, by rolling backwards and forwards over the linen spread upon a polished table underneath, render it smooth and level. The moving wheel, being furnished with teeth upon both surfaces of its periphery, and having a notch cut out at one part, allows a pinion, uniformly driven in one direction, to act alternately upon its outside and inside, so as to cause the reciprocating motion of the chest. This elegant and much-admired English invention, called the mangle-wheel, has been introduced with great advantage into the machinery of the textile manufactures.

Mr. Warcup, of Dartford, obtained a patent several years ago for a mangle in which the linen, being rolled round a cylinder revolving in stationary bearings, is pressed downwards by heavy weights hung upon its axes, against a curved bed, made to slide to and fro, or traverse from right to left, and left to right, alternately.

Mr. Hubie, of York, patented in June 1832 another form of mangle, consisting of three rollers placed one above another in a vertical frame, the axle of the upper roller being pressed downwards by a powerful spring. The articles intended to be smoothed are introduced into the machine by passing them under the middle roller, which is made to revolve by means of a fly-wheel; the pinion upon whose axis works in a large toothed wheel fixed in the shaft of the same roller. The linen, &c. is lapped, as usual, in protecting cloths. This machine is merely a small CALENDER.

MANGROVE. Several tropical trees yield woods to which this name has been applied. Colonel G. A. Lloyd informs us, that 'the timbers are very much valued for ship-building; and a large quantity comes from Crab Island and Porto Rico.' Most of the mangroves belong to the *Rhizophoraceæ.*

MANILLA. One of the hemps, derived from the *Musa textilis.* See HEMP.

MANIOC is the Indian name of the nutritious matter of the shrub *Jatropha Manihot,* from which *cassava* and *tapioca* are made in the West Indies. See CASSAVA; TAPIOCA.

MANNA is the concrete saccharine juice of the *Fraxinus ornus,* a tree much cultivated in Sicily and Calabria. It is now little used, and that only in medicine.

MANNHEIM GOLD. A brass, containing 80 per cent. of copper and 20 per cent. of zinc.

MANURE. Under the auspices of the British Association, Professor Liebig, in the year 1840, first promulgated his views on agriculture, from which date we may trace a spirit of investigation into it, such as had not previously existed in this country. Among other labourers in this field, we must state that Mr. J. B. Lawes, of Rothamstead in Hertfordshire, was occupied several years prior to the first edition of Professor Liebig's work, in investigating the action of different chemical combinations when applied as manures to the more important crops of the farm; and having ever since continued his experimental researches with all the lights of science with which he is familiar, aided by Dr. J. H. Gilbert, a skilful analytical chemist, he has been able to arrive at conclusions of greater value and precision than the merely theoretical determinations of the German Professor. In the course of this inquiry, the whole tenor of the results of Messrs. Lawes and Gilbert, and also of information derived from intelligent agricultural friends, upon every variety of land in Great Britain, has forced upon them opinions different from those of Professor Liebig, on some important points; and more especially, in relation to his so-called 'mineral theory,' which is embodied in the following sentence, to be found at page 211 of the third edition of his work on Agricultural Chemistry, where he says 'the crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it in manure.'

Of the vast importance, both in a scientific and practical point of view, of correct ideas on the subject here at issue, a judgment may be formed from the manner in which Liebig himself speaks of the mineral theory in this edition of his 'Letters on Chemistry.' Thus he says of the agriculturists of England, that 'sooner or latter they must see that in the so-called mineral theory, in its development and ultimate perfection, lies the whole future of agriculture.' Messrs. Lawes and Gilbert published the following paper in reply to Liebig. It is of so important a nature that, acting on the advice of the best authority in this country, it has been retained:—

'Looking upon the subject in a chemical point of view only, it would seem that an analysis of the soil upon which crops were to be experimentally grown, as well as a knowledge of the composition of the crop, should be the first points ascertained, with the view of deciding in what constituents the soil was deficient; and, at the commencement of our more systematic course of field experiments, the importance of these points was carefully considered. When we reflect, however, that an acre of soil six inches deep may be computed to weigh about 1,344,000 lbs. (though the roots of plants take a much wider range than this), and taking the one constituent of ammonia or nitrogen as an illustration, that in adding to this quantity of soil a quantity of ammoniacal salt, containing 100 lbs. of ammonia, which would be an unusually heavy and very effective dressing, we should only increase the percentage of ammonia in the soil by 0·0007, it is evident that our methods of analysis would be quite incompetent to appreciate the difference between the soil before and after the application,—that is to say, in its state of exhaustion, and of highly productive condition, so far as that constituent is concerned; and, from our knowledge of the effects of this substance on wheat, we may confidently assert that the quantity of it supposed above would have given a produce at least double that of the unmanured land. The same kind of argument might, indeed, be adopted in reference to the more important of those constituents of a soil which are found in the ashes of the plant grown upon it, and we determined, therefore, to seek our results in another manner. Indeed, the imperfection of our knowledge of the productive quality of a soil, as derived from its percentage composition, has been amply proved by the results of analysis which have been published during the last ten years; and in corroboration, we need only refer to the opinions of Professor Magnus on this subject, who, in his capacity of chemist to the 'Landes-Oekonomie Kollegium' of Prussia, has published the result of many analyses of soils. The truth is, that little is as yet known of what a soil either is, or ought to be, in a chemical point of view; but when we call to mind the investigations of Professor Mulder in relation to the organic acids found in soils, and of Mr. Way and others as to the chemical and physical properties of soils in relation to the atmosphere and to saline substances exposed to their action in solution, we may at least anticipate for chemistry that she will ere long throw important light on this interesting but intricate subject.

'In our field experiments, then, we have been satisfied with preserving specimens of the soils which were to be the subjects of them, and have sought to ascertain their deficiency, in regard to the production of different crops, by means which we conceive to be not only far more manageable, but in every way more conclusive and satisfactory in their result. To illustrate: What is termed a rotation of crops is at least of such universality in the farming of Great Britain, that any investigation in relation to the agriculture of that country may safely be grounded on the supposition of its adoption. Let us, then, direct attention for a moment to some of the chief features of rotations. What is called a *course* of rotation is the period of years which includes the circle of all the different crops grown in that rotation or alternation. The crops which thus succeed each other, and constitute a rotation, may be two, three, four, or more, varying with the nature of the soil and the judgment of the farmer; but whatever *course* be adopted, no individual crop—wheat, for example--is grown immediately succeeding one of the same description, but it is sown again only after some other crops have been grown, and at such a period of the rotation, indeed, as by experience it is known that the soil will, by direct manure or other means, have recovered its capability of producing a profitable quantity of the crop in question.

'On carefully considering these established and well-known facts of agriculture, it appeared to us that, by taking soils either at the end of the rotation, or at least at that period of it when in the ordinary course of farming farmyard manure would be added before any further crop would be grown, we should then have the soils in what may be termed a *normal*, or, perhaps better still, a *practically* and *agriculturally* exhausted, state.

'Now, if it is found, in the experience of the farmer, that land of any given quality, with which he is well acquainted will not, when in this condition of practical exhaustion, yield the quantity he usually obtains from it of any particular crop, but that after applying farmyard manure it will do so, it is evident that if we supply to different plots of this *exhausted land* the constituents of farmyard manure both individually and combined, and if by the side of these plots we also grow the crop both without manure of any kind and with farmyard manure, we shall, in the comparative results obtained, have a far more satisfactory solution of the question as to what constituents were, in this ordinary course of agriculture most in defect in respect to the proportion of the particular crop experimented upon, than any analysis of the soil could have given us. In other words, we should have before us very good ground for deciding to which of the constituents of the farmyard manure the increased produce was mainly due on the plot provided with it, in the case of the particular crops: not so, however, unless the soil had been so far exhausted by previous cropping as to be considered *practically* unfit for the growth of the crop without manure. We lay particular stress on this point, because we believe that the vast discrepancy in the results of comparative trials with different manures, by different experiments, arises more from irregularity in what may be called the *floating* capital of the soil, than from irregularities in the original character of the soil itself, or from any other cause, unless we include the frequent faulty methods of application.

'It is, then, by this *synthetic* rather than by the analytic method that we have sought our results: and in the carrying out of our object we have taken *wheat* as the type of the *cereal* crops, *turnips* as the type of the *root* crops, and *beans* as the representative of the *leguminous corn* crop most frequently entering into rotation; and having selected for each of these a field which, agriculturally considered, was *exhausted*, we have grown the same description of crop upon the same land, year after year, with different chemical manures, and in each case with one plot or more continuously unmanured, and one supplied every year with a fair quantity of farmyard manure. In this way 14 acres have been devoted to the continuous growth of *wheat* since 1843, 8 acres to continuous growth of *turnips* from the same date, and 5 to 6 acres to that of *leguminous corn* crops since 1847. And of field experiments, beside these, which amount in each year to from 30 to 40 on wheat, upwards of 90 on turnips, and 20 to 30 on beans, others have been made, viz. some on the growth of clover, and some in relation to the chemical circumstances involved in an actual course of rotation, comprising turnips, barley, clover, and wheat, grown in the order in which they are here stated.

'It may be stated, too, that in addition to these experiments on wheat, and the other crops usually grown upon the farm, as above referred to, we have for several years been much occupied also with the subject of the feeding of animals, viz. bullocks, sheep, and pigs; as well as in investigating the functional actions of the growing plant in relation to the soil and atmosphere; and in connection with each of these subjects much laboratory labour has constantly been in progress.

'The scope and object of our investigation has been therefore to examine in the field, the feeding-shed, and the laboratory, into the chemical circumstances connected with the agriculture of Great Britain in its four main features; namely—

'First, the production of the cereal grain crops; secondly, that of root crops; thirdly, that of the leguminous corn and fodder crop; and, fourthly and lastly, that of the consumption of food on the farm, for its double produce of meat and manure.

'So much then for the rationale and general plan of the experiments themselves, and we now propose to call attention to some of the results which they have afforded us.

'It is to field experiments on wheat that we shall chiefly confine our attention on this occasion; for wheat, which constitutes the principal food of our population, is with the farmer the most important crop in his rotation, all others being considered more or less subservient to it; and it is, too, in reference to the production of this crop in agricultural quantity that the mineral theory of Baron Liebig is perhaps more prominently at fault than in that of any other. It is true, that in the case of vegetation in a native soil manured by art, the mineral constituents of the plants being furnished from the soil, the atmosphere is found to be a *sufficient* source of the nitrogen and carbon; and it is the supposition that these circumstances of *natural vegetation* apply equally to the various crops when grown *under cultivation* that has led Baron Liebig to suggest that, if by artificial means we accumulate within the soil itself a sufficiently liberal supply of those constituents found in the ashes of the plant, essentially soil constituents, we shall by this means be able in all cases to increase thereby the assimilation of the vegetable or atmospheric constituents in a degree sufficient for agricultural purposes. But agriculture is itself an *artificial* process; and it will be found that, as regards the production of wheat more especially, it is only by the accumulation within the soil itself of nitrogen *naturally* derived from the atmosphere, rather than of the peculiarly soil constituents, that our crops of it can be increased. Mineral substances will, indeed, materially develope the accumulation of vegetable or atmospheric constituents when applied to *some* of the crops of rotation; and it is thus chiefly that these crops become subservient to the growth of the cereal grains; but even in these cases it is not the constituents, *as found collectively in the ashes of the plants to be grown*, that are the most efficient in this respect; nor can the demand which we find thus made for the production of crops in *agricultural quantity* be accounted for by the mere idea of supplying the *actual* constituents of the crop. It would seem, therefore, that we can only arrive at correct ideas in agriculture by a close examination of the actual circumstances of growth of each particular crop when grown under cultivation. We now turn to the consideration of our experiments upon this subject. It has been said that all the experimental fields were selected when they were in a state of agricultural exhaustion. The wheat fields, however, after having been manured in the usual way for turnips at the commencement of the previous rotation, had then grown barley, peas, wheat, and oats, without any further manuring; so that when taken for experiment in 1844, it was, as a grain-producer, considerably more exhausted than would ordinarily be the case. It was, therefore, in a most favourable condition for the purposes of our experiments.

'In the first experimental season, the field of 14 acres was divided into about 20 plots, and it was by the *mineral theory* that we were mainly guided in the selection of manures: mineral manures were therefore employed in the majority of cases. *Ammonia*, on the other hand, being then considered of less importance, was used in a few instances only, and in these in very insignificant quantities. Rape-cake, as being a well-recognised manure, and calculated to supply, besides some minerals and nitrogen, a certain quantity of carbonaceous substance in which both corn and straw so much abound, was also added to one or two of the plots.

Table I.—*Harvest* 1844. *Summary.*

Description of the manures	Dressed corn per acre, in bushels and pecks		Total corn per acre, in lbs.	Straw per acre, in lbs.
	bush.	pecks	lbs.	lbs.
Plot 3. Unmanured	16	0	923	1120
„ 2. 14 tons of farmyard manure	22	0	1276	1476
„ 4. The ashes of 14 tons of farm manure	16	0	888	1104
„ 8. Minimum produce of 9 plots, with artificial mineral manures Superphosphate of lime, 350 lbs. Phosphate of potass, 364 lbs.	16	1	980	1160
„ 15. Maximum produce of 9 plots with artificial mineral manures Superphosphate of lime, 350 lbs. Phosphate of magnesia, 168 lbs. „ potass, 150 lbs. Silicate of potass, 112 lbs.	17	3¼	1096	1240
Mean of the 9 plots with artificial mineral manures	16	3¾	1009	1155
Mean of 3 plots with mineral manures, and 65 lbs. each of sulphate of ammonia	21	0	1275	1423
Mean of 2 plots with mineral manures, and 150 lbs. and 130 lbs. of rape-cake respectively	18	1¾	1078	1201
Plot 18. With complex mineral manure, 65 lbs. of sulphate of ammonia, and 150 lbs. of rape-cake	22	3¼	1368	1768

'The indications of the table are seen to be most conclusive, as showing what was the character of the exhaustion which had been induced by the previous heavy cropping, and what therefore, should be the peculiar nature of the supply in a rational system of manuring. If the exhaustion had been connected with a deficiency of mineral constituents, we might reasonably have expected that by some one at least of the nine mineral conditions,—supposing in some cases an abundance of every mineral constituent which the plant could require,—this deficiency would have been made up; but it was not so.

'Thus, taking the column of bushels per acre as given in this summary as our guide, it will be seen that whilst we have without manure only 16 bushels of dressed corn, we have by farmyard manure 22 bushels. The *ashes* of farmyard manure give, however, no increase whatever over the unmanured plot. Again, out of the 9 plots supplied with artificial mineral manures, we have in no case an increase of two bushels by this means; the produce of the average of the 9 being not quite 17 bushels. On the other hand, we see that the addition to some of these purely mineral manures of 65 lbs. of sulphate of ammonia—a very small dressing of that substance, and containing only about 14 lbs. of ammonia—has given us an average produce of 21 bushels. An insignificant addition of rape-cake too, to manures otherwise ineffective, has given us about 18½ bushels; and when, as in plot 18, we have added to the inefficient mineral manures 65 lbs. of ammoniacal salts, and a little rape-cake also, we have a produce greater than by the 14 tons of farmyard manure.

'The quantities of rape-cake used were small, and the increase attributable to it also small, but it nevertheless was much what we should expect when compared with that from the ammoniacal salts, if, as we believe is the case, the effect of rape-cake on *grain-crops* is due to the nitrogen it contains.

'Indeed, the coincidence in the slight or non-effect throughout the mineral series on the one hand, and of the marked and nearly uniform result of the nitrogenous supply on the other, was most striking in the first year's experimental produce, and such as to lead us to give to nitrogenous manures in the second season even greater prominence than we had done to minerals in the previous one. This is, in some respects, perhaps, to be regretted, as had we kept a series of plots for some years continuously under minerals alone, the evidence, though at present sufficiently conclusive, would have carried with it somewhat more of *systematic* proof.

'In Table II. we have given a few results selected from those obtained at the harvest of 1845, the second of the experimental series. By the table it would seem that we have, at the harvest of 1845, a produce of rather more than 23 bushels without manure of any kind, instead of only 16 as in 1844; and in like manner the farmyard manure gives 32 bushels in 1845, and only 22 in 1844.

TABLE II.—*Harvest* 1845. *Selected Results.*

Description and quantities of the manures per acre	Dressed corn per acre, in bushels and pecks		Total corn per acre, in lbs.	Straw per acre, in lbs.
	bush.	pecks	lbs.	lbs.
Section 1.				
Plot 3. No manure	23	0¾	1441	2712
,, 2. 14 tons of farmyard manure	32	0½	1967	3915
Section 2.				
,, *5a.* No manure	22	2¼	1431	2684
,, *5b.* Top-dressed with 252 lbs. of carbonate of ammonia (dissolved) at 3 times, during the spring	26	3¾	1732	3599
Section 3.				
,, 9. Sulphate of ammonia, 168 lbs. Muriate of ammonia, 168 lbs. } top-dressed at once	33	1½	2131	4058
,, 10. Sulphate of ammonia, 168 lbs. Muriate of ammonia, 168 lbs. } top-dressed at 4 times	31	3¼	1980	4266

'We assume, then, 23 bushels or thereabouts to be the standard produce of the soil and season, without manure, during this second experimental year; and as part of plot 5 (previously manured with superphosphate of lime), and which is now also without manure, gives rather more than 22½ bushels of dressed corn, the correctness of the result of plot 3, the permanently unmanured plot, is thereby fully confirmed.

'This plot No. 5, previously two thirds of an acre, was, in this second year, divided into two equal portions: one of these ('plot *5a*') being, as just said, unmanured, and the other ('plot *5b*') having supplied to it in solution, by top-dressings during the spring, the *medicinal carbonate of ammonia*, at the rate of 250 lbs. per acre; and it is seen that we have, by this pure but highly volatile ammoniacal salt alone, the produce raised from 22½ bushels to very nearly 27 bushels!

'In the next section of the Table are given the results of plots 9 and 10, the former of which had in the previous year been manured by superphosphate of lime and a small quantity of sulphate of ammonia, and the latter by superphosphate of lime and silicate of potass. To each of these plots 1½ cwt. of sulphate and 1½ cwt. of muriate of ammonia were now supplied. Upon plot 9 the whole of the manure was top-dressed, *at once*, early in the spring; but on plot 10 the salts were put on at four successive periods. The produce obtained by these salts of ammonia alone is 33 bushels and three-eighths, when sown all at once, and nearly 32 bushels when sown at four different times—quantities which amount to about 10 bushels per acre more than was obtained without manure. In the case of No. 9, indeed, the produce exceeds by 1¼ bushel that given by farmyard manure, and in that of No. 12 it is all but identical with it. And if we take the weights of total corn, instead of the *measure* of the dressed corn, to which latter we chiefly refer, merely as a standard more conventionally understood, No. 10 by ammonia only, has given both more corn and more straw than the farmyard manure, with all its minerals and carbonaceous substance.

'Let us see whether this almost specific effect of nitrogen, in restoring, for the reproduction of corn, a corn-exhausted soil, is borne out by the results of succeeding years.

'We should have omitted all reference to the results obtained with the wheat manure of Professor Liebig, but that whilst fully admitting the failure of the manure—the composition of which, to use his own words when commenting upon it, 'could be no secret, since every plant showed by its ashes the due proportion of the constituents essential to its growth'—he implied that the failure was due to a yet imperfect knowledge of the mechanical form and chemical qualities required to be given to the necessary constituents in order to fit them for their reception and nutritive action on the plant, rather than to any fallacy in the theory which would recommend to practical agriculture the supply by artificial means of the constituents of the ashes of plants as manures.

'The following Table gives our selection of the results of the third season, 1846 :—

TABLE III.—*Harvest* 1846. *Selected Results.*

Descriptions and quantities of the manures per acre	Dressed corn per acre, in bushels and pecks		Total corn per acre, in lbs.	Straw per acre, in lbs.
	bush.	pecks	lbs.	lbs.
Section 1.				
Plot 3. No manure	17	3¾	1207	1513
„ 2. 14 tons of farmyard manure . . .	27	0¾	1826	2454
Section 2.				
„ 10*b*. No manure	17	2½	1216	1455
„ 10*a*. Sulphate of ammonia, 224 lbs. . .	27	1½	1850	2244
Section 3.				
„ 5*a*¹. Ash of 3 loads of wheat-straw . .	19	0½	...	1541
„ 5*a*². Ash of 3 loads of wheat-straw, and top-dressed with 224 lbs. of sulphate of ammonia	27	0	...	2309
Section 4.				
„ 6*a*. Liebig's wheat-manure, 448 lbs. . .	20	1½	1400	1676
„ 5*a*. Liebig's wheat-manure, 448 lbs., with 112 lbs. each of sulphate and muriate of ammonia	29	0¾	1967	2571

'At this third experimental harvest we have on the continuously unmanured plot, namely, No. 3, not quite 18 bushels of dressed corn, as the normal produce of the season; and by its side we have on plot 10*b*—comprising one half of the plot 10 of the previous years and so highly manured by ammoniacal salts in 1845, but now unmanured,—rather more than 17½ bushels. The near approach, again, to identity of result from the two unmanured plots, at once gives confidence in the accuracy of the experiments, and shows us how effectually the preceding crop had, in a practical point of view, reduced the plots, previously so differently circumstanced both as to manure and produce, to something like an uniform standard as regards their grain-producing qualities. We take this opportunity of particularly calling attention to these coincidences in the amount of produce in the two unmanured plots of the different years, because it had been objected against our experiments, as already published, that confirmation was wanting as to the natural yield of soil and season.

'Plot 2 has, as before, 14 tons of farmyard manure, and the produce is 27¼ bushels, or between 9 and 10 bushels more than without manure of any kind.

'On plot 10*a*, which in the previous year gave with ammoniacal salts alone a produce equal to that of the farmyard manure, we have again a similar result: for 2 cwts. of sulphate of ammonia has now given 1850 lbs. of total corn, instead of 1826 lbs., which is the produce on plot 2. The straw of the latter is, however, slightly heavier than that by the ammoniacal salt.

'Again, plot 5*a*, which was in the previous season *unmanured*, was now subdivided: on one half of it (namely, 5*a*¹) we have the ashes of wheat-straw alone, by which there is an increase of rather more than 1 bushel per acre of dressed corn; on the other half (5*a*²) we have, besides the straw-ashes, 2 cwts. of sulphate of ammonia put on as a top-dressing; 8 cwts. of sulphate of ammonia have, in this case, only increased the produce beyond that of 5*a*¹ by 7⅞ bushels of corn and 768 lbs. of straw, instead of by 9⅝ bushels of corn and 789 lbs. of straw, which was the increase obtained by the same amount of ammoniacal salt on 10*a*, as compared with 10*b*. It will be observed, however, that in the former case the ammoniacal salts were top-dressed, but in the latter they were drilled at the time of sowing the seed; and it will be remembered that in 1845 the result was better *as to corn* on plot 9, where the salts were sown earlier than on plot 10, where the top-dressing extended far into the spring. We have had several direct instances of this kind in our experience, and we would give it as a suggestion, in most cases applicable, that manures for wheat, and especially ammoniacal ones, should be applied before or at the time the seed is sown; for, although the apparent luxuriance of the crop is greater, and the produce of straw really heavier, by spring rather than autumn sowings of Peruvian guano and other ammoniacal manures, yet we believe that that of the *corn* will not be increased in an equivalent degree. Indeed, the success of the crop undoubtedly depends very materially on the progress of the underground growth during the winter months; and this again, other things being equal, upon the quantity of available nitrogenous constituents within the soil, without a liberal provision of which, the range of the fibrous feeders of the plants will not be such as to take up the minerals which the soil is competent to supply, and in such quantity as will be required during the after-progress of the plant for its healthy and favourable growth.

'The next result to be noticed is that obtained on plot 6, now also divided into two equal portions, designated respectively 6*a* and 6*b*. Plot No. 6 had for the crop of 1844 superphosphate of lime and the phosphate of magnesia manure, and for that of 1845 superphosphate of lime, rape-cake, and ammoniacal salts. For this the third experimental season, it was devoted to the trial of the wheat-manure manufactured under the sanction of Professor Liebig, and patented in this country.

'Upon plot 6*a*, 4 cwts. per acre of the patent wheat-manure were used, which gave 20½ bushels, or rather more than two bushels beyond the produce of the unmanured plot; but as the manure contained, besides the minerals peculiar to it, some nitrogenous compounds, giving off a very perceptible odour of ammonia, some, at least, of the increase would be due to that substance. On plot 6*b*, however, the further addition of 1 cwt. each of sulphate and muriate of ammonia to this so-called 'mineral manure' gives a produce of 29¼ bushels. In other words, the addition of ammoniacal salt to Liebig's mineral manure has increased the produce by very nearly 9 bushels per acre beyond that of the mineral manure alone, while the increase obtained over the unmanured plot by 14 tons of farmyard manure was only 9¼ bushels.

'If, then, the "mechanical form and chemical qualities" of the so-called "mineral manure" were at fault, the sulphate of ammonia has, at least, compensated for the defect; and even supposing a mineral manure, founded on a knowledge of the composition of the ashes of the plant, be still the great desideratum, the farmer may rest contented, meanwhile, that he has in ammonia, supplied to him by Peruvian guano, by ammoniacal salts, and by other sources, so good a substitute.

'It surely is needless to attempt further to justify, by the results of individual years, our assertion, that in practical agriculture nitrogenous manures are peculiarly adapted to the growth of wheat. We shall therefore conclude this part of our subject by directing attention to the history of a few of the plots throughout the entire series of years, as compared with that of the unmanured plot during the same period.

'In support of the view that leguminous plants do possess a superior power of reliance upon the atmosphere for their nitrogen, and, indeed, that it is to this property that they materially owe their efficacy in rotation with grain, we may refer to the admirable investigations into the chemistry of agriculture of M. Boussingault. His experiments, however, have not received the attention which they merit from the agriculturists of this country; probably on account of the small amounts of produce which he obtained. But it must be remembered that his investigation had for its object to explain the practices of agriculture as he found them in his own locality, before attempting to deviate from its established rules. M. Boussingault states the rotation usually adopted at Bechelbronn, and throughout the greater part of Alsace, to be as follows:—

"Potatoes or beet-root;" "Wheat;" "Clover;" "Wheat;"

and that the average of wheat so obtained is, after potatoes 19½ bushels, after beet-root 17 bushels, and after clover 24 bushels. Now we find by reference to his table that the first crop of wheat, grain, and straw removed 17 lbs. of phosphoric acid and 24 lbs. of potash and soda; the following clover crop, 18 lbs. of phosphoric acid and 77 lbs. of potash and soda; and after this removal of alkalis and phosphates by the clover, a *larger* crop of wheat is obtained. Surely it would seem impossible to reconcile this result with a theory which supposes the produce of wheat to rise and fall with the quantity of minerals available within the soil. If, however, we admit that the first crop of wheat could not take up the mineral matters existing in the soil for want of nitrogenous supply, and that the clover crop, not being so dependent upon *supplied* nitrogen, was able to take up the minerals required for its growth, and that it moreover left in the soil sufficient ammonia or its equivalent of nitrogen in some form, to give the *increased* crop of wheat, we have a much more consistent and probable solution of the results. There is little doubt that M. Boussingault could have increased his produce of wheat by means of ammoniacal salts: whether he could have done so economically is another question, depending of course upon the relative prices of grain and ammonia.

'The striking effect of phosphoric acid upon the growth of the turnip, indeed, is a fact so well known to every intelligent agriculturist in Great Britain, that it would seem quite superfluous to attempt to illustrate it by any direct experiments of our own. However, as Professor Liebig has again, in the recent edition of his 'Letters,' expressed an opinion entirely inconsistent with such a result, we will refer to one or two of the results obtained in our experimental turnip-field, which bear on the opinion he has reiterated as follows:—thus, speaking of the exhaustion of phosphate of lime and alkaline phosphates by the sale of flour, cattle, &c., he says:—"It is certain that this incessant removal of the phosphates must tend to exhaust the land and diminish its capability of producing grain. The fields of Great Britain are in a state of progressive exhaustion from this cause, as is proved by the rapid extension of the cultivation of turnips and mangold-wurzel, plants which contain the least amount of the phosphates, AND THEREFORE REQUIRE THE SMALLEST QUANTITY FOR THEIR DEVELOPMENT." Now we do not hesitate to say that, however small the quantity of phosphates contained in the turnip, the successful cultivation of it is more dependent upon a large supply of phosphoric acid in the manure than that of any other crop.

'In the following Table, then, is given the amount of bulb, from 1843 to 1850.

First, the continuously unmanured plot:—
Secondly, that with a large amount of the superphosphate of lime alone each year; and
Thirdly, that with a very liberal supply of potash, with some soda and magnesia also in addition to superphosphate of lime.

Years	Plot continuously unmanured				Plot with Superphosphate of Lime alone every year				Plot with superphosphate of lime and mixed alkalis			
	tons	cwts.	qrs.	lbs.	tons	cwts.	qrs.	lbs.	tons	cwts.	qrs.	lbs.
1843	4	3	3	2	12	3	2	8	11	17	2	0
1844	2	4	1	0	7	14	3	0	5	13	2	0
1845	0	13	2	24	12	13	3	12	12	12	2	8
1846		...		...	1	18	0	0	3	10	1	20
1847		...		...	5	11	0	1	5	16	0	0
1848		...		...	10	11	0	8	9	14	2	0
1849		...		...	3	15	0	0	3	13	2	8
1850		...		...	11	9	0	0	9	7	1	12
Totals .		...		...	65	16	1	1	62	5	1	20
Means .		...		...	8	4	2	4	7	15	2	20

'It is seen, then, that in the third season, viz. 1845, the produce of the unmanured plot is reduced to a few hundredweights, and since that period the size of the bulbs had been such that they had not been considered worth weighing. On the other hand, on the plot with *superphosphate of lime alone* for eight successive years, we have an average produce of about 8¼ tons of bulb! varying however exceedingly year by year, according to the season. We see, too, that by the addition to superphosphate of lime of a large quantity of the alkalis, much greater than could be taken off in the crop, the average produce is not so great by nearly half a ton as by the superphosphate of lime alone. It must be admitted that this extraordinary effect of superphosphate of lime cannot be accounted for by the idea of merely supplying in it the actual constituents of the crop, but that it is due to some special agency in developing the assimilative processes of the plant. The opinion is favoured by the fact that in the case where the superphosphate of lime is at once neutralised by alkalis artificially supplied, the efficacy of the manure would seem to be thereby reduced. And, from this again, we would gather that the effect of the phosphoric acid, as such, cannot be due merely to the liberation within the soil of its alkalis, or we should suppose that the artificial supply of these would at least have been attended with some increase of produce. But this is not the case, notwithstanding that by means of superphosphate of lime alone there has been taken from the land more of the alkalis in which the ash of the turnip so peculiarly abounds, than would have been lost to it in a century under the ordinary course of rotation and home manuring! Collateral experiments also clearly prove the importance of a liberal supply of organic substance rich in *carbon*—which always contains a considerable quantity of nitrogen also—if we would in practical agriculture increase the yield much beyond the amount which can be obtained by mineral manures alone, and these conditions being fulfilled, the direct supply of nitrogen, on the other hand, is by no means so generally essential. And it is where we have provided a liberal supply of constituents for organic formations, in addition to the mineral manures, that we have found the use of alkalis not to be without effect.

'But it is at any rate certain that phosphoric acid, though it forms so small a proportion of the ash of the turnip, has a very striking effect on its growth when applied as manure; and it is equally certain that the extended cultivation of root crops in Great Britain cannot be due to the deficiency of this substance for the growth of corn, and to the less dependence upon it of the root crops, as supposed by Baron Liebig.

'These curious and interesting facts in relation to the growth of turnips, as well as those which have been given in reference to wheat and to the leguminous crops, are sufficient to prove how impossible it is to form correct opinions on agricultural chemistry without the guidance of direct experiment in the field. And we are convinced that if Baron Liebig had watched the experiments which we have had in progress during the last eight years, he would long ago have arrived at conclusions in the main agreeing with those to which we have been irresistibly led.

'So much, then, for the results of experiments in the field, and for the considerations in relation to the functional actions of plants, as bearing upon the character of the manure required for their growth in a course of practical agriculture. Let us now consider for a few moments what really are the main and characteristic features of practical agriculture, as most generally followed in this country.

'Let us suppose that the rotation adopted is that of Turnips, Barley, Clover, Wheat: that the turnips and clover are consumed upon the farm by stock, and that the meat thus produced, 40 bushels of barley, and 30 bushels of wheat, are all the exports from the farm; the manure from the consumed turnips and clover, and the straw, both of barley and of wheat, being retained on the farm. We have in this case, by the sale of grain, a loss of minerals to each acre of the farm of only 20 to 24 lbs. of potass and soda, and 26 to 30 lbs. of phosphoric acid, in the centre of the rotation, or an average of 5 to 6 lbs. of potass and soda, and 6½ to 7½ lbs. of phosphoric acid per acre per annum. In the sale of the animals there would of course be an additional loss of phosphoric acid, though especially if no breeding-stock were kept, this would be even much less considerable than in that of the grain; and the amount of the alkalis thus sent off the farm would, according to direct experiments of our own upon calves, bullocks, lambs, sheep, and pigs, probably be only about one-fourth that of the phosphoric acid. It has, however, long been decided in practical agriculture that phosphoric acid may be advantageously provided in the purchase of bones or other phosphatic manures, though in practice these are not found applicable as a direct manure for the wheat crop; and as we have already said, even when employed for the turnip, its efficacy is not to be accounted for merely as supplying a sufficiency of that substance to be stored up in the crop.

'In conclusion, then: if the theory of Baron Liebig simply implies that the growing plant must have within its reach a sufficiency of the mineral constituents of which it is to be built up, we fully and entirely assent to so evident a truism; but if, on the other hand, he would have it understood that it is of the mineral constituents, as would be *collectively* found in the ashes of the exported produce, that our soils are deficient relatively to other constituents, and that, in the present condition of agriculture in Great Britain, "we cannot increase the fertility of our fields by a supply of nitrogenised products, or by salts of ammonia alone, but rather that their produce increases or diminishes, in a direct ratio, with the supply of mineral elements capable of assimilation," we do not hesitate to say that every fact with which we are acquainted, in relation to this point, is unfavourable to such a view. We have before stated, however, that, if a *cheap* source of ammonia were at command, the available mineral constituents might in their turn become exhausted by its excessive use.'

MANURE, ARTIFICIAL. Agricultural writers usually divide manures into two classes, natural and artificial.

The first division includes farmyard manure, liquid manure, and the various composts that are occasionally made by farmers from excrementitious matters, earth, lime, and all sorts of refuse matters found or produced on the farm.

In the second division we find guano, bone-dust, nitrate of soda, sulphate of ammonia; also the waste of slaughter-houses, night-soil, the refuse of glue-makers, wool waste, and other refuse materials of certain factories; and likewise superphosphate of lime, blood manure, and a great variety of saline mixtures, which are now extensively manufactured in manure works, for the purpose of supplying farmers with special chemical fertilisers, such as wheat-, barley-, oat-, potato-, flax-manure, &c. The term artificial manure thus includes a great variety of different materials, and is frequently applied to products which, like guano, are in point of fact much more natural than farmyard manure, in the successful preparation of which a certain amount of skill is required on the part of the farmer. The evident anomaly of considering guano, bones, blood, and nitrate of soda (Chili saltpetre) as artificial manures, has led some agricultural writers to describe them under natural manures. Again, others apply the term artificial only to compound saline manuring mixtures, such as wheat- and grass-manures, or to manures the preparation of which necessitates a certain acquaintance with chemical principles and the use of chemical agents. All this confusion can be avoided entirely, if manures, instead of being divided into natural and artificial, were separated into home-made manures, that is, manures produced from the natural resources of the farm, and into imported manures, that is, fertilisers which are introduced on the farm from foreign sources.

The term 'artificial,' more appropriately, is given to all simple or compound fertilisers in the production of which human art has been instrumental. In this signification we shall use the term 'artificial manure.'

Not many years ago farmyard manure was universally considered the only efficient fertiliser to restore the fertility of land, impaired by a succession of crops. Recent agricultural experience, however, has shown that, in a great measure, artificial manures may be employed with advantage instead of yard manure, nay, that in several respects artificial manures are preferable to ordinary dung. Indeed, the present advanced state of British agriculture is intimately connected with the success with which artificial manures have been introduced into the ordinary routine on the farm.

The variety of artificials in present use amongst English farmers is very great. Some, like well prepared samples of superphosphate, are unquestionably manures distinguished for high fertilising properties; others are less efficacious, or of a doubtful character; and not a few hardly repay the cost of carriage beyond a distance of 10 miles. The fact that in almost every market-town artificial manures are sold, which, if not altogether worthless, offer, to say the least, no profitable investment to the occupier of land, shows plainly that the principles which ought to regulate the manufacture of artificial manures are not so generally understood as it is desirable they should be. In comparison with other branches of industrial art, the manufacture of manures is comparatively simple, and involves no very expensive machinery beyond steam-power for the pulverisation of the raw materials; nor does it necessitate extensive practical experience, or the possession of a large stock of chemical knowledge, on the part of the manufacturer. The limits of this article preclude the detailed description of all the artificial manures that find their way at present into the manure market; nor does it appear to us necessary to mention in detail the various proportions in which the numerous refuse materials used by manure-makers may be blended together into efficacious fertilisers; for a manufacturer who is thoroughly acquainted with the nature of artificial manures, and the legitimate uses to which they ought to be applied, will find little or no difficulty when working up into artificial manures the raw materials or refuse matters for the acquirement of which a particular locality may offer peculiar advantages. A right conception of the relative commercial and agricultural value of the different constituents that enter into the composition of manures is the chief desideratum for the manufacturer of artificial manure. We therefore propose to refer, in the following pages, briefly to the more important principles which ought to be kept steadily in view in establishments erected for the supply of artificial fertilisers.

The high esteem in which good farmyard manure is held by practical men, its uniformly beneficial effect upon almost every kind of crop, and the economical advantages with which it is usually applied to the land, have induced many to regard farmyard manure as the model which the manufacturer of artificial manure should endeavour to imitate. But this proposition is wrong in principle, as will be shown presently, and its adoption in manure-works has led to disappointment and ruin. It would be foreign to our object to give in this place a full account of the peculiar merits that belong to yard manure, and to compare them with those exhibited by artificial manures. Each has its peculiar merits and disadvantages, upon which we need not dwell in this article. It will help us, however, in properly comprehending what is really required in a good artificial manure, if we inquire briefly into the composition of good yard manure. We therefore subjoin an analysis, made some time ago by Dr. Voelcker, of well-rotted farmyard manure (see next page):—

Farmyard manure contains all the constituents which our cultivated crops require to come to perfection, and is suited for every description of agricultural produce. As far as the inorganic fertilising substances are concerned, we find in farmyard manure potash, soda, lime, magnesia, oxide of iron, phosphoric acid, sulphuric acid, hydrochloric and carbonic acid; in short, all the minerals that are found in the ashes of agricultural crops.

Of organic fertilising substances, we find in farmyard manure some which are readily soluble in water, and containing a large portion of nitrogen; and others insoluble in water, and containing, comparatively speaking, a small proportion of nitrogen. The former readily yield ammonia, the latter principally give rise to the formation of humic acids, and similar organic compounds. These organic acids constitute the mixture of organic matters, which in practice pass under the name of humus.

Composition of Farmyard Rotted Dung (Horses', Cows', and Pigs'), in 100 parts.

Water		75·42
Soluble organic matter[1]		3·71
Soluble inorganic matter (ash):—		
Soluble silica	·254	
Phosphate of lime	·382	
Lime	·117	
Magnesia	·047	
Potash	·446	
Soda	·023	
Chloride of sodium	·037	
Sulphuric acid	·058	
Carbonic acid and loss	·106	
		1·47
Insoluble organic matter[2]		12·82
Insoluble inorganic matter (ash):—		
Soluble silica	1·424	
Insoluble silica	1·010	
Oxides of iron and alumina, with phosphates	·947	
Containing phosphoric acid	(·274)	
Equal to bone-earth	(·573)	
Lime	1·667	
Magnesia	·091	
Potash	·045	
Soda	·038	
Sulphuric acid	·063	
Carbonic acid and loss	1·295	
		6·58
		100·00

Farmyard manure thus is a perfect manure, for experience and analysis alike show that it contains all the fertilising constituents required by plants, in states of combination which appear to be especially favourable to the luxuriant growth of our crops.

On most farms the supply of common yard manure is inadequate to meet the demands of the modern system of high farming. Hence the endeavour of enterprising men to supply this deficiency by converting various refuse materials into substitutes for farmyard manure. Artificial manures likely to approach farmyard manure in their action should contain all the elements in the latter, and in a state of combination, in which they are neither too soluble nor too insoluble; for it is evident that a plant can grow luxuriantly, and come to perfect maturity only when all the elements necessary for its existence are presented to it in a state in which they can be assimilated by the plant.

But the question arises, Is it desirable to produce by art perfect substitutes for common dung? We think not, for the following reasons:—

In the first place, well-rotted dung contains in round numbers two-thirds of its weight of water, and only one-third of its weight of dry matter. A large bulk therefore contains, comparatively speaking, but a small proportion of fertilising-matters. In every 3 tons of manure we have to pay carriage for 2 tons of water; and it may be safely asserted that no manure, however efficacious it may be in a dry condition, will be found an economic substitute for farmyard manure, if it cannot be produced in a much drier condition than common yard manure.

Again, several of the constituents which greatly preponderate in farmyard manure are present in most soils in abundant quantities; they need not, therefore, be supplied to the land in the form of manure; or, should they be wanting in the soil, they can be readily obtained almost everywhere at a cheap rate. If, therefore, these inexpen-

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[1]

Containing nitrogen	·297
Equal to ammonia	·36

[2]

Containing nitrogen	·309
Equal to ammonia	·375
Whole manure containing ammonia in free state	·046
" " form of salts	·057

sive and more widely distributed substances are dispensed with in compounding a manure, and those are selected which occur in soils only in minute quantities, a very valuable and efficacious fertiliser is obtained, which possesses the great advantage of containing in a small bulk all the essential fertilising substances of a large mass of home-made dung.

That the effect which every description of manure is capable of producing depends on its composition is self-evident; and as the different constituents which generally enter into the composition of manures produce different effects upon vegetation, it is of primary importance to the manufacturer of manure that he should be acquainted with the special mode of action of each fertilising constituent.

We shall therefore make some observations on the practical effects, and the comparative value, of the various constituents that enter into the composition of manures.

To guard against misapprehension, we would observe that, in one sense, all the fertilising-agents are alike valuable; for they are all indispensable for the healthy condition of our cultivated crops, and consequently the absence of one is attended with serious consequences, though all others may be present in abundance. Thus the deficiency of lime in the land is attended with as much injury to the plant as that of phosphoric acid. In this sense lime is as valuable as phosphoric acid; but inasmuch as lime is generally found in most soils in abundant quantities, or, if deficient, can be applied to the land economically in the form of slaked lime, marl, shell-sand, &c., its presence in an artificial manure is by no means a recommendation to it.

The principal constituents of manures are:—

1. Nitrogen (in the shape of ammonia, nitric acid, and nitrogenised organic matters).
2. Phosphoric acid (bone-earth and soluble phosphates).
3. Potash (carbonate and silicate of potash).
4. Soda (common salt).
5. Lime and magnesia (carbonate and sulphate of lime and magnesia).
6. Soluble silica.
7. Humus-forming organic matters (vegetable remains of all kinds).
8. Sulphuric acid (sulphate of lime).
9. Chlorine (common salt).
10. Oxide of iron, alumina, silica (clay, earth, and sand).

We have here mentioned these constituents in the order which expresses their comparative commercial value.

1. *Nitrogen.*—This element may be incorporated with artificial manures in the shape of ammoniacal salts or nitrates, or nitrogenised organic matters.

The cheapest ammoniacal salt is sulphate of ammonia; the cheapest nitrate is Chili saltpetre, or nitrate of soda; hence sulphate of ammonia and nitrate of soda are exclusively employed by manure manufacturers for the preparation of nitrogenised manures, when no organic refuse-matters containing nitrogen, such as horn-shavings, bone-dust, woollen rags, blood, glue-refuse, &c., are available.

Nitrogen in any of these forms exercises a most powerful action in manure, especially when applied to plants at an early stage of their growth; at a later period of development the application of ammoniacal salts or nitrate of soda appears much less effective, and sometimes even useless. For this reason nitrogenised manures, such as guano, soot, specially-prepared wheat-manures, &c., ought to be applied either in autumn or in spring, immediately after the young blade has made its appearance above ground.

Ammoniacal salts, nitrate of soda, and decomposed nitrogenised organic matters, have a most marked effect upon the leaves of plants; they induce a rapid and luxuriant development of leaves, and may therefore be called leaf-producing or forcing manures. Grass, wheat, oats, and other cereals, when grown upon soils containing abundance of available mineral elements, are strikingly benefited by a nitrogenised manure; but, on account of their special action, they ought to be used with caution in the case of corn-crops, and always more sparingly on light than on heavy land; otherwise, fine straw, but little and an inferior sample of grain, will be obtained.

As a general rule, ammoniacal salts or nitrate of soda should not be used by farmers in a concentrated state, and exceptionally only. However useful sulphate of ammonia or nitrate of soda may be in a particular case, it ought to be remembered that generally such manures produce beneficial effects only in conjunction with mineral matters. If, therefore, a proper amount of available mineral substances does not exist in the soil, it has to be supplied in the manure. Ammoniacal salts, nitrate of soda, animal matters, &c., are therefore almost always blended together with phosphates, common salt, gypsum, &c., by manufacturers of manures.

Whilst we thus fully recognise the importance of the presence of ammonia, ammoniacal salts, nitrates, or animal matters furnishing ammonia on decomposition in manures, especially in manures for white crops, we cannot agree with those who estimate the entire value of manuring-substances by the proportion of nitrogen which they contain.

In a purely commercial sense, nitrogen in the shape of ammonia or nitric acid, or animal nitrogenised matters, is the most valuable fertilising constituent, for it fetches a higher price in the market than any other manuring constituent.

2. *Phosphoric Acid.*—Next in importance follows phosphoric acid. This acid exists largely in the grain of wheat, oats, barley, in leguminous seeds, likewise in turnips, mangolds, carrots, in clover, meadow-hay, and, in short, in every kind of agricultural produce. Whether we grow, therefore, a cereal crop or a fallow crop, there must be phosphoric acid in sufficient quantity in the soil, or if insufficient it must be added to the land in the shape of manure.

The proportion of phosphoric acid in even good soils is very small, and as the agricultural produce in almost every case removes from the soil more of phosphoric acid than of any other soil-constituent, the want of available phosphoric acid makes itself known very soon. This is especially the case with quick-growing crops, such as turnips, mangolds, &c. The whole period of vegetation of these green crops extends only over 4 or 5 months, and the fibrous roots of these crops are unable to penetrate, like wheat, the soil to any considerable depth. For these reasons, phosphoric acid in some form or other has to be abundantly supplied to root-crops; and experience has shown that no description of fertilising matter benefits roots so much as superphosphate and similar manures, which contain phosphate of lime in a state in which it is readily assimilated by plants.

In artificial manures phosphoric acid commonly occurs in the shape of bone-dust, boiled bones, bone-shavings (refuse of knife-handle makers, turners of ivory, buttonmakers, &c.), or in the state of biphosphate of lime, purposely manufactured from bone materials or from phosphatic minerals.

The phosphate of lime which occurs in fresh bones, practically speaking, is insoluble in water. In water charged with carbonic acid, and still more so in water containing some ammonia, it is more soluble than in pure water. On fermenting bone-dust in heaps it becomes a much more effective manure. Such fermented bone-dust is added with much benefit to general artificial manures.

All really good artificial manures should contain a fair proportion of phosphate—say from 25 to 40 per cent., according to the uses for which the manure is intended. Generally speaking, manures for turnips, and root-crops in general, should be rich in phosphates especially soluble phosphates (biphosphate of lime); such manures need not contain more than 1 to 1½ per cent. of ammonia, and, when used on land in a tolerably good agricultural condition, ammonia can be altogether omitted in the manure without fear of deteriorating the efficacy of the manure.

3. *Potash.*—Salts of potash unquestionably are valuable fertilising constituents, for potash enters largely into the composition of the ashes of all crops. Root-crops especially require much potash; hence these crops are much benefited by wood-ashes, burnt clay, liquid manure, and other fertilisers containing much potash.

The commercial resources of potash are limited, and salts of potash have generally been far too expensive to be employed largely in the manufacture of artificial manures. Fortunately potash exists abundantly in most soils containing a fair proportion of clay. Its want in artificial manures therefore is not perceived, at least not in the same degree in which the deficiency of phosphates in a manure would be felt. Of late years however valuable deposits of potash-salts have been discovered at Stassfurt in Prussian Saxony, and have been extensively employed for various industrial purposes, including the preparation of manures.

4. *Soda.*—Salts of soda are much less efficacious fertilising matters than salts of potash. There are few soils which do not contain naturally enough soda, in one form or the other, to satisfy the wants of the crops which are raised upon them. However, common salt is largely employed in the manufacture of artificial manures; if it does no good, it certainly does no harm; and in this country it is one of the cheapest diluents which can be employed for reducing the expenses of concentrated fertilising mixtures to a price at which they can be sold to farmers. In continental districts common salt proves more efficacious as a manure than in England, where the neighbourhood of the sea provides the majority of soils with plenty of salt, which by the winds is carried landwards with the spray of the sea to very considerable distances.

Salt, however, even in England, is usefully applied to mangolds, and enters largely into the composition of most artificial manures expressly prepared for this crop.

5. *Lime and Magnesia.*—All plants require lime and magnesia in smaller or larger quantities. Many soils contain lime in superabundance; in others it is deficient. To the latter soils it must be added. This can be done by lime-compost, by slaked lime, by marl, shell-sand, or gypsum. All these calcareous manures are cheap almost everywhere, for lime and magnesia are among the most widely distributed, and most abundant mineral substances.

The addition of chalk, marl, and even gypsum, to artificial manures, should therefore be avoided as much as possible.

At the best, carbonate and sulphate of lime in artificial manures must be regarded as diluents.

6. *Soluble Silica.*—The artificial supply of soluble silica to the land, as far as our present experience goes, has done no good whatever to cereals, the straw of which soluble silica is supposed to strengthen.

In the absence of reliable practical experiments with soluble silica, we cannot venture to recommend the use of silicate of soda or soluble silica to manure-manufacturers.

7. *Organic substances; Humus.*—The importance of organic matters free from nitrogen, as fertilising agents, is very trifling. Formerly the value of a manure was estimated by the amount of organic matter it contained, and little or no difference was made whether the organic matter contained nitrogen or not. Under good cultivation, the organic matter in the soil regularly increases from year to year; there exists therefore no necessity of supplying it in the shape of manure.

In artificial manures we should certainly exclude all substances that merely add to the bulk, without enhancing the real fertilising value of the manure. Peat, saw-dust, and similar organic matters, &c., are useful to the manure-maker only as diluents and absorbents of moisture.

8. *Sulphuric acid* is another constituent of manure, which possesses little value. In artificial manures sulphuric acid chiefly occurs as gypsum.

9. *Chlorine.*—Exists in manures principally as salt.

10. *Oxide of Iron, Alumina, Silica.*—These constituents exist sometimes in manures in the shape of burnt-clay, earth, brick-dust, and sand.

It is hardly necessary to remark that good artificial manures should contain as little as possible of these matters.

It will appear from the preceding observations, that nitrogen in the shape of ammoniacal salts, nitric acid or decomposed animal matters, and phosphoric acid are the most valuable fertilising constituents.

The manufacturers of artificial manure should therefore endeavour:

1. To produce manures containing as little water as possible.
2. To incorporate as much of nitrogenised organic matters, or ammoniacal salts, or nitrates and phosphates, in general manuring mixtures, as is possible at the price at which artificial manures are usually sold.
3. To avoid as much as possible gypsum, salt, peat-mould, chalk, and other substances that chiefly add to the bulk, without increasing the efficacy, of the manures.

He should also endeavour to produce uniform finely-pulverised articles, that run readily through the manure drill.

It likewise devolves on the manufacturer of manures to render more effective, that is to say, more rapid and energetic in their action, refuse materials which may remain inactive in the soil for years before they enter into decomposition, and to reduce by chemical means into a more convenient state for assimilation, raw materials, which like coprolites, apatite, &c., produce little or no beneficial effects upon vegetation, even when added to the land in a finely-powdered condition.

At the present time, two classes of artificial manures may be distinguished: 1, general manures, *i.e.* manures which profess to suit equally well every kind of agricultural produce; and 2, special manures, *i.e.* manures specially prepared for a particular crop only.

The requirements of different crops, or perhaps, more correctly speaking, the conditions that regulate the assimilation of food, vary so much, that we doubt the policy of manure-makers to prepare *general* artificial manures. At the same time, we doubt the necessity of preparing artificial manures for every description of crop. Special manures are extremely useful to farmers, if they are prepared by intelligent manufacturers, who possess sufficient chemical knowledge to take advantage of every improvement that is made in manufacturing chemistry, and at the same time know sufficient of agriculture to understand what is really wanted in a soil. In other words, except a manufacturer is a good practical chemist and a tolerably good farmer, he will not be able properly to adapt the composition of special fertilisers to the nature of the soil, and the peculiar mode of treatment which the land has received on the part of the farmer.

However, nearly all special artificial manures, generally speaking, may be arranged under two heads. They are either: 1. Nitrogenised Manures, or, 2. Phosphatic Manures. The first may be used with almost equal advantage for wheat, barley, oats, for rye, and on good land likewise for grass. The second are chiefly used for root-crops.

Nitrogenised artificial manures frequently are nothing more than guano, diluted with gypsum, salt, peat-mould, earth, &c. In fact, guano is the cheapest ammoniacal manure; for which reason it is so largely employed for compounding low-priced wheat-manures, grass-manures, &c. &c.

Good manures for cereals may be made by blending together fine bone-dust, or bone-dust dissolved in sulphuric acid, sulphate of ammonia, salt, and gypsum. These manures will be the better the more sulphate of ammonia they contain. In 1873 we imported 70,055 tons of bones of animals and fish for this purpose.

Turnip-manures, and artificial manures for root-crops in general, consist principally of dissolved bones, or dissolved coprolites and other mineral phosphates. They are, in fact, superphosphates of various degrees of concentration. The more soluble phosphate a root-manure contains, the better is it adapted to the purpose for which it is used.

Most samples of superphosphate contain little or no ammonia, or nitrogenised organic matters.

Blood-manure is a superphosphate, in the preparation of which some blood is used.

In preparing superphosphate from bones, it is essential that they should be reduced to fine dust. This is moistened with about $\frac{1}{3}$ its weight of water, after which another third to one half of brown sulphuric acid is added. The pasty mass is allowed to cool, in the mixing vessel, or when large quantities are prepared, the semi-liquid mass in the mixer is run out still hot, fresh quantities of bone-dust, water, and acid are put in the mixer, and after 5 or 10 minutes the contents allowed to run out, and a fresh quantity prepared as before. The successive mixings are all kept together in one heap for 1 or 2 months; the heap is then turned over, and if necessary, the partially-dissolved bones are passed through a riddle.

In a similar manner, coprolites, bone-ash, apatite and other phosphatic minerals are treated with acid. It ought to be observed, however, that the quantity of brown sulphuric acid necessary for dissolving coprolites must be at least $\frac{3}{4}$ths of the weight of coprolite powder, for coprolites contain much carbonate of lime, which neutralises sulphuric acid. Even 75 per cent. of brown acid are not always sufficient to dissolve completely coprolite powder, and as the proportion of carbonate of lime in coprolites and phosphatic minerals varies considerably, it cannot be stated definitely what amount of oil of vitriol should be used in every case. The safest plan, therefore, for the manufacturer is, to ascertain from time to time whether the proportion of acid which he has used has converted nearly the whole of the insoluble phosphates in coprolites into soluble phosphates, and if necessary to add more acid. In the case of bone-dust, it does not matter if the whole of the bone-earth is not rendered soluble; bones even partially acted upon by oil of vitriol, become sufficiently soluble in the soil to prove efficacious for the turnip crop. But the case is different, if mineral phosphates, such as apatite or coprolite powder, are employed in the manufacture of superphosphate. Insoluble phosphates in the shape of coprolite powder are not worth anything in an artificial manure, for they are too insoluble to be taken up by the turnip crop. It is therefore essential to employ a quantity of acid, which is amply sufficient to convert the whole of the insoluble phosphate of lime in coprolites into soluble, or biphosphate of lime.—A. V. See APATITE; COPROLITES; PHOSPHATES.

We exported, in 1873, artificial manures to the value of 671,550*l*.

MAPLE, or *Plane.* (*Erable*, Fr.; *Ahorn*, Ger.) *Acer campestre,* the English or field maple. The wood of this tree is compact and finely veined; it is used in France and other parts of the Continent for furniture, and it makes excellent charcoal.

Acer platanoides. The Norway maple. This wood is soft, but being finely grained is capable of receiving a good polish, and looks well.

Acer pseudo-platanus. Sycamore, great maple, or false plane. The wood is of a compact grain, and does not warp or become worm-eaten.

Acer saccharum. Sugar maple. This tree is extensively cultivated in America for the sugar which is extracted from it. The wood is frequently used for furniture, having a silky lustre when polished.

Acer striatum. Striped barked maple. This tree is grown in America, and as the wood is finely grained and white, it is much used as a substitute for holly by furniture-makers.

The Russian maple is thought to be the wood of a birch-tree. It differs in many respects from the American maple, but is sometimes used as a substitute for it.

The bird's-eye maple is the American variety, the best being obtained from Prince Edward's Island. The mottled maple is a commoner variety.

MARBLE. This title embraces such of the primary, transition, and purer compact limestones of the secondary formation, as may be quarried in solid blocks without fissures, and are susceptible of a fine polished surface. The finer the white, the more beautifully variegated the colours of the stone, the more valuable, *cæteris paribus*, is the marble. Its general characters are the following:—

Marble effervesces with acids; affords quicklime by calcination; has a conchoïdal scaly fracture; is translucent only on the very edges; is easily scratched by the knife; has a spec. grav. of 2·7; admits of being sawn into slabs; and receives a brilliant polish. These qualities occur united in only three principal varieties of limestone: 1, in the saccharoid limestone, so called from its fine granular texture resembling that of loaf-sugar, and which constitutes modern statuary marble, like that of Carrara; 2, in the foliated limestone, consisting of a multitude of small facets formed of little crystalline plates applied to one another in every possible direction, constituting the antique statuary marble, like that of Paros; 3, in many of the Devonian and Carboniferous, or *encrinitic* limestones, which occur below the coal formation.

The saccharoid and lamellar, or statuary marbles, belong entirely to metamorphic districts. The greater part of the close-grained coloured marbles belong also to the same geological localities; and become so rare in the more recent limestone formations, that immense tracts of these occur without a single bed sufficiently entire and compact to constitute a workable marble. The limestone lying between the Great Oolite and the Cornbrash of the lower oolite, and which is called 'Forest marble' in England, being susceptible of a tolerable polish, and variegated with imbedded shells, has sometimes been worked into ornamental slabs in Oxfordshire, where it occurs in the neighbourhood of Wychwood forest; but this case can hardly be considered as an exception to the general rule. Even higher in the geological series, marbles may occasionally be worked; thus the Purbeck and Wealden series yield shelly bands of freshwater limestone, which, under the names of Purbeck marble, Sussex marble, &c., have been largely used for the clustered shafts in Gothic architecture.

To constitute a profitable marble-quarry, there must be a large extent of homogeneous limestone, and a facility of transporting the blocks after they are dug. On examining these natural advantages of the beds of Carrara marble, we may readily understand how the statuary marbles discovered in the Pyrenees, Savoy, Corsica, &c. have never been able to come into competition with it in the market. In fact, the two sides of the valley of Carrara may be regarded as mountains of statuary marble of the finest quality.

The various tints of ornamental marbles generally proceed from oxides of iron; but the blue and green tints are sometimes caused by minute particles of hornblende, as in the slate-blue variety called Turchino, and in some green marbles of Germany. The black marbles are coloured by carbon, mixed occasionally with sulphur and bitumen; when they constitute 'stinkstone.'

Brard divides marbles, according to their localities, into classes, each of which contains eight subdivisions:—

1. Uni-coloured marbles; including only the white and the black.
2. Variegated marbles; those with irregular spots or veins.
3. Madreporic marbles, presenting animal remains in the shape of white or grey spots, with regularly disposed dots and stars in the centre.
4. Shell marbles; with only a few shells interspersed in the calcareous base.
5. Lumachella marbles, entirely composed of shells.
6. Cipolin marbles, containing veins of greenish talc.
7. Breccia marbles, formed of a number of angular fragments of different marbles, united by a common cement.
8. Pudding-stone marbles; a conglomerate of rounded pieces.

Antique marbles.—The most remarkable of these are the following:—*Parian marble*, called *Lychnites* by the ancients, because its quarries were worked by lamps; it has a yellowish-white colour, and a texture composed of fine crystalline facets, lying in all directions. The celebrated Arundelian marbles at Oxford consist of Parian marble, as does also the Medicean Venus. *Pentelic marble*, from Mount Penteles, near Athens, resembles the Parian; but is somewhat denser and finer grained, with occasional greenish zones produced by greenish talc, whence it is called by the Italians *Cipilino statuario.* The Parthenon, Propylæum, the Hippodrome, and other principal monuments of Athens, were of Pentelic marble; of which fine specimens may be seen among the Elgin collection, in the British Museum. *Marmo Greco*, or Greek white marble, is of a very lively snow-white colour, rather harder than the preceding, and susceptible of a very fine polish. It was obtained from several islands of the Archipelago, as Scio, Samos, Lesbos, &c. *Translucent white marble, Marmo statuario* of the Italians, is very much like the Parian, only not so opaque. Columns and altars of this marble exist in Venice, and several towns of Lombardy; but the quarries are quite unknown. *Flexible white marble*, of which five or six tables are preserved in the house of Prince Borghese, at Rome. The *White marble of Luni*, on the coast of Tuscany, was preferred by the Greek sculptors to both the Parian and Pentelic. *White marble of Carrara*, between Spezzia and Lucca, is of a fine white colour, but often traversed by grey veins, so that it is difficult to procure moderately large pieces free from them. It is not so apt to turn yellow as the Parian marble. This quarry was worked by the ancients, having been opened in the time of Julius Cæsar. Many antique statues remain of this marble. Its two principal quarries at the present day are those of Pianello and Polvazzo. In the centre of its block very limpid rock crystals are sometimes found, which are called 'Carrara diamonds.' As the finest qualities are becoming excessively rare, it has risen in price to about 3 guineas the cubic foot. The *White marble* of Mount Hymettus, in Greece, was not of a very pure white, but inclined a little to grey. The statue of Meleager, in the French Museum, is of this marble.

Black antique marble, the *Nero antico* of the Italians. This is more intensely black than any of our modern marbles; it is extremely scarce, occurring only in sculptured pieces. The *red antique marble*, *Egyptum* of the ancients, and *Rosso antico* of the Italians, is a beautiful marble of a deep blood-red colour, interspersed with white veins and with very minute white dots, as if strewed over with grains of sand. There is in the Grimani Palace at Venice a colossal statue of Marcus Agrippa in *rosso antico*, which was formerly preserved in the Pantheon at Rome. *Green antique marble, verde antico*, is a kind of breccia, whose paste is a mixture of talc and limestone, while the dark green fragments consist of serpentine. Very beautiful specimens of it are preserved at Parma. The best quality has a grass-green paste, with black spots of noble serpentine, but is never mingled with red spots. *Red spotted green antique marble* has a dark green ground marked with small red and black spots, with fragments of *entrochi* changed into white marble. It is known only in small tablets. *Leek marble*; a rare variety of that colour of which there is a table in the Mint at Paris. *Marmo verde pagliocco* is of a yellowish-green colour, and is found only in the ruins of ancient Rome. *Cervelas marble*, of a deep red, with numerous grey and white veins, is said to be found in Africa, and highly esteemed in commerce. *Yellow antique marble, giallo antico* of the Italians; colour of the yolk of an egg, either uniform or marked with black or deep yellow rings. It is rare, but may be replaced by Sienna marble. *Red and white antique marbles*, found only among the ruins of ancient Rome. *Grand antique*, a breccia marble, containing shells, consists of large fragments of a black marble, traversed by veins or lines of a shining white. There are four columns of it in the Museum at Paris. *Antique Cipolino marble*: Cipolin is a name given to all such marbles as have greenish zones produced by green talc; their fracture is granular and shining, and displays here and there plates of talc. *Purple antique breccia marble* is very variable in the colour and size of its spots. *Antique African breccia* has a black ground, variegated with large fragments of a greyish-white, deep red, or purplish wine colour; and is one of the most beautiful marbles. *Rose-coloured antique breccia* marble is very scarce, occurring only in small tablets. There are various other kinds of ancient breccia, which it would be tedious to particularise.

Modern Marbles.—1. British. Black marble is found at Ashford, Matlock, and Bonsaldale in Derbyshire; and in the south part of Devonshire. The variegated marbles of Devonshire are generally reddish, brownish, and greyish, variously veined with white and yellow, or the colours are often intimately blended; the marbles from Torbay and Babbacombe display a great variety in the mixture of their colours; the Plymouth marble is either ash-coloured with black veins, or blackish-grey and white shaded with black veins; the cliffs near Marychurch exhibit marble quarries not only of great extent, but of superior beauty to any other in Devonshire, being either of a dove-coloured ground with reddish-purple and yellow veins, or of a black ground mottled with purplish globules. The green marble of Anglesea is not unlike the *verde antico*; its colours being greenish-black, leek-green, and sometimes dull purplish irregularly blended with white. The white part is limestone, the green shades proceed from serpentine and asbestos. There are several fine varieties of marble in Derbyshire; the mottled-grey in the neighbourhood of Moneyash, the light-grey being rendered extremely beautiful by the number of purple veins which spread upon its polished surface in elegant irregular branches; but its chief ornament is the multitude of *entrochi* with which this limestone marble abounds. Much of the transition and carboniferous limestone of Wales and Westmoreland is capable of being worked up into agreeable dark marbles.

In Scotland a fine variety of white marble is found in beds at Assynt in Sutherlandshire. A beautiful ash-grey marble, of a very uniform grain, and susceptible of a fine polish, occurs on the north side of the ferry of Ballachulish in Invernessshire. One of the most beautiful varieties is that from the hill of Belephetrich in Tiree, one of the Hebrides. Its colours are pale blood-red, light flesh-red, and reddish-white, with dark-green particles of hornblende, or rather sahlite, diffused through the general base. The compact marble of Iona is of a fine grain, a dull-white colour, somewhat resembling pure compact felspar. It is said by Bournon to consist of an intimate mixture of tremolite and carbonate of lime, sometimes with yellowish or greenish-yellow spots. The carboniferous limestone of many of the coal-basins in the Lowlands of Scotland may be worked into a tolerably good marble for chimney-pieces.

In Ireland the Kilkenny marble is the one best known, having a black ground more or less varied with white marks produced by fossils. The spar which occupies the place of the shells sometimes assumes a greenish-yellow colour. An exceedingly fine black marble has also been raised at Crayleath in the county of Down. At Louthlougher, in the county of Tipperary, a fine purple marble is found. The county of Kerry affords several variegated marbles not unlike the Kilkenny; and a fine reddish marble is quarried in the county Cork. A serpentinous limestone in Connemara forms a prettily variegated green marble known as 'Irish green.'

France possesses a great many marble quarries, which have been described by Brard, and of which a copious extract is given under the article *Marble*, Rees's *Cyclopædia*.

The territory of Genoa furnishes several beautiful varieties of marble, the most remarkable of which is the *polzevera di Genoa*, called in French the *vert d'Egypte* and *vert de mer*. It is a mixture of granular limestone with a talcose and serpentine substance disposed in veins; and it is sometimes mixed with a reddish body. This marble was formerly much employed in Italy, France, and England, for chimney-pieces, but its sombre appearance has put it out of fashion. Among the Genoese marbles we may notice the highly-esteemed variety called *portor*, on account of the brilliant yellow veins in a deep black ground. The most beautiful kind comes from Porto Venese; and Louis XIV. caused a great deal of it to be worked up for the decoration of Versailles. It costs now 2*l.* per cubic foot.

Corsica possesses a good statuary marble, of a fine close grain, and pure milky-whiteness, quarried at Ornofrio; it will bear comparison with that of Carrara: also a grey marble (*bardiglio*), a cipolin, and some other varieties. The island of Elba has immense quarries of a white marble with blackish-green veins.

Among the innumerable varieties of Italian marbles, the following deserve especial notice:—

The *rovigio*, a white marble found at Padua. The white marble of St. Julien, at Pisa, of which the cathedral and celebrated slanting tower are built. The Biancone marble, white with a tinge of grey, quarried at Maguregа for altars and tombs. Near Mergozza a white marble with grey veins is found, with which the cathedral of Milan is built. The black marble of Bergamo is called *paragone*, from its black colour, like touchstone; it has a pure, intense tint, and is susceptible of a fine polish. The pure black marble of Como is also much esteemed. The *polveroso* of Pistoya is a black marble sprinkled with dots; and the beautiful white marble with black spots, from the Lago Maggiore, has been employed for decorating the interior of many churches in the Milanese. The Margorre marble, found in several parts of the Milanese, is bluish veined with brown, and composes part of the dome of the cathedral of Milan. The green marble of Florence owes its colour to a copious admixture of serpentine. Another green marble, called *verde di Prado*, occurs in Tuscany, near the little town of Prado. It is marked with spots of a deeper green than the rest, passing even into blackish-blue. The beautiful Sienna marble, or *brocatello di Siena*, has a yellow colour like the yolk of an egg, which is disposed in large irregular spots, surrounded with veins of bluish-red, passing sometimes into purple. At Montarenti, two leagues from Sienna, another yellow marble is met with, which is traversed by black and purplish-black veins. The Brema marble is yellow, with white spots. The *mandelatò* of the Italians is a light-red marble with yellowish-white spots, found at Luggezzana, in the Veronese. The red marble of Verona is of a red rather inclining to yellow or hyacinth; a second variety, of a dark red, composes the vast amphitheatre of Verona. Another marble is found near Verona, with large white spots in a reddish and greenish paste: very fine columns have been made of it. The *occhio di pavone* is an Italian shell-marble, in which the shells forms large orbicular spots, red, white, and bluish. A madreporic marble, known under the name of *pietra stellaria*, much employed in Italy, is entirely composed of star madrepores, converted into a grey-and-white substance, and is susceptible of an excellent polish. The village of Bretonico, in the Veronese, furnishes a splendid breccia marble, composed of yellow, steel-grey, and rose-coloured spots. That of Bergamo consists of black and grey fragments in a greenish cement. Florence marble, called also ruin and landscape marble, is an indurated calcareous marl.

Sicily abounds in marbles, the most valuable of which is that called by the English stone-cutters Sicilian jasper; it is red, with large stripes like ribands, white, red, and sometimes green, which run zigzag with pretty acute angles.

Of Cutting and Polishing Marble.—The marble-saw is a thin plate of soft iron, continually supplied during its sawing-motion with water and the sharpest sand. The sawing of moderate pieces is performed by hand, but that of large slabs is most economically done by a proper mill.

The first substance used in the polishing process is the sharpest sand, with which the marble must be worked till the surface becomes perfectly flat. Then a second, and even a third sand of increasing fineness is to be applied. The next substance is emery of progressive degrees of fineness, after which tripoli is employed; and the last polish is given with tin-putty. (See PUTTY-POWDER.) The body with which the sand is rubbed into the marble is usually a plate of iron; but for the subsequent process, a plate of lead is used with fine sand and emery. The polishing-rubbers are coarse linen cloths, or bagging, wedged tight into an iron planing-tool. In every step of the operation a constant trickling supply of water is required.

MARCASITE, or white iron pyrites, is of a pale bronze-yellow, or iron-grey colour, with a metallic lustre. It is a bisulphide of iron, composed of iron 46·7, sulphur 63·3. Specific gravity 4·678 to 4·847.

The mineral was formerly much used for various ornaments, as shoe- and knee-buckles, pins, bracelets, setting of watch-cases, &c.; and, although the taste for it has considerably declined now, probably owing in some degree to its abundance, immense quantities are still cut and manufactured at Geneva and in the French Jura.

The marcasite of commerce is generally small, rarely attaining the size of a stone of two carats. It takes a good polish, and is cut in facets like rose-diamonds. In this state it possesses all the bright blue of polished steel, without the tendency of the latter to become oxidised by exposure to the action of the atmosphere. It is principally procured from Germany and the Jura.—H. W. B. See PYRITES.

MARCASITE. Bismuth was formerly so called. See BISMUTH.

MARGARATES are saline compounds of margaric acid with the bases.

MARGARIC ACID (*Margarine*) is one of the acid fats produced by saponifying tallow with alkaline matter, and decomposing the soap with dilute acid. The term *margaric* signifies pearly-looking.

The physical properties of the margaric and stearic acids are very similar; the chief difference is that the former is more fusible, melting at 140° Fahr. The readiest mode of obtaining pure margaric acid is to dissolve olive-oil soap in water, to pour into the solution a solution of neutral acetate of lead, to wash and dry the precipitate, and then to remove its oleate of lead by ether, which does not affect its margarate of lead. The residuum being decomposed by boiling-hot muriatic acid, affords margaric acid. When heated in a retort this acid boils. It is insoluble in water, very soluble in alcohol and ether; it reddens litmus-paper, and decomposes, with the aid of heat, the carbonates of soda and potash.

Margaric acid is obtained most easily by the distillation of stearic acid. The humidity at the beginning of the process must be expelled by a smart heat, otherwise explosive ebullitions are apt to occur. Whenever the ebullition becomes uniform, the fire is to be moderated. See OILS.

MARINA. A name given to madder after it has undergone a peculiar treatment. See Crookes's 'Handbook of Dyeing.'

MARINE ACID. Hydrochloric acid was formerly so called because it could be obtained from sea-water. See HYDROCHLORIC ACID and MURIATIC ACID.

MARINE METAL. A name for Wetterstedt's alloy, which was introduced as a sheathing for ships. It consisted of lead 94·4, antimony 4·3, and mercury 1·3. It was said not to be attacked by sea-water, and to remain free from vegetable or animal growth.

MARINE SALT. See SALT.

MARJORAM. The *Origanum majorana*, one of the *Labiatæ*, is used as an aromatic herb, and yields *oil of marjoram* on distillation.

MARL (*Marne*, Fr.; *Mergel*, Ger.) is a mixed earthy substance, consisting of carbonate of lime, clay, and siliceous sand, in very variable proportions; it is sometimes compact, sometimes pulverulent. According to the predominance of one or other of these ingredients, marls are distributed into calcareous, clayey, and sandy.

MARLSTONE. One of the members of the Lias formation. The Cleveland iron ore occurs in the marlstone, or middle lias. See LIAS.

MARMATITE. A variety of blende, in which part of the zinc is replaced, sometimes by iron, and sometimes by cadmium. It is found at Marmato in Popayan.

MAROON. A peculiar deep-red colour produced, according to Crookes ('Handbook of Dyeing') in the following manner:—

Boil 20 lbs. of cudbear, or 25 lbs. of orchil, and 4 ounces of magenta crystals, for ten minutes. Cool the dye to 175° Fahr.; enter the wool; increase the temperature to 212°; remove, rinse, and dry.

MAROOL. A vegetable fibre from the *Sanseviera Zeylanica.* See FIBRES.

MARQUETRY is a peculiar kind of cabinet-work, in which the surface of wood is ornamented with inlaid pieces of various colours and forms. The *marqueteur* puts gold, silver, copper, tortoise-shell, mother-of-pearl, ivory, horn, &c., under contribution. These substances, being reduced to laminæ of proper thinness, are cut out into the desired form by punches, which produce the full pattern or mould, and the empty one, which enclosed it; and both serve their separate purposes. A mosaic wood-work was much practised in Italy in the fifteenth century which very much resembled marquetry. It was called Tarsia (*Tarsiatura*, Ital.). The art was cultivated to the greatest extent in the Venetian territories, and was much employed in decorating the choirs of churches, the backs of seats, and the panels of doors. In Mrs. Merrifield's 'Ancient Practice of Painting' it is well described. See TARSIA; PARQUETRY.

MARSH-GAS. Light carburetted hydrogen. This gas is the fire-damp of the coal-miner. See FIRE-DAMP INDICATOR; VENTILATION.

MARSH ROSEMARY. (*Statica Carolinianæ.*) This plant is found along the sea-coast in marshy situations from Maine to Florida. The root has been used for tanning. According to Professor Parrish, it contains 12 per cent. of tannin.

MARTIAL. Belonging to iron; from Mars, the old name of this metal.

MARTIUS-YELLOW. A name sometimes applied to naphthaline yellow.

MASSICOT. Yellow oxide of lead. The old name of litharge. See LITHARGE.

MASTIC (Eng. and Fr.; *Matsix*, Ger.) is a resin produced by making incisions in the *Pistacia lentiscus*, a tree cultivated in the Levant, and chiefly in the island of Chios. It comes to us in yellow, brittle, transparent, rounded tears; which soften between the teeth, with bitterish taste and aromatic smell, and a specific gravity of 07·1. Mastic consists of two resins; one soluble in dilute alcohol. Its solution in spirit of wine constitutes a good varnish. It dissolves also in turpentine. See VARNISH.

MASTIC CEMENT. A mixture of lime, sand, litharge, and linseed-oil.

MATCHES. See LUCIFER MATCHES.

MATRASS is a bottle with a thin, egg-shaped bottom, much used for digestions in chemical researches.

MATTE is a crude black copper, reduced, but not refined, from sulphur and other heterogeneous substances. A matte is simply a regulus, or fused sulphide.

MAUVE, or *Perkin's Violet.* The earliest aniline colour introduced into commerce has lost much of its importance. Kunge had previously called attention to the violet coloration produced on treating aniline with chromic acid or the hypochlorites. In August 1856 Mr. Perkin patented his process for the production of a violet colouring-matter from aniline. See ANILINE-VIOLET.

Among the very large number of new methods proposed for the manufacture of this dye, especially after the spring of the year 1859, we may notice the following:—

Messrs. Depouilly and South's method, patented in June 1860, consisted in adding to a salt of aniline a solution of chloride of lime, which yielded a purple insoluble precipitate. This was repeatedly washed in slightly-acidulated water, dissolved in concentrated sulphuric acid, and re-precipitated by the addition of an excesssof water. It was then simply necessary to wash the precipitate thoroughly, in order to render it fit for use if dissolved in alcohol or methylated spirit. The chloride of lime process gives a more abundant yield than the bichromate method, but the tone of the violets obtained is redder and less pure. We may here mention that Mr. W. H. Perkin has lately succeeded in obtaining the product of Runge's experiment in the solid condition. He finds that it dissolves in alcohol, forming a solution of a nearly pure blue colour, which is changed to a brownish-red by the action of caustic alkali; it therefore differs essentially from the mauve; an alcoholic solution of which, if treated with caustic alkali, passes from purple to violet. The blue product, which the author proposes to call 'Runge's blue,' undergoes a very remarkable change when subjected to the action of heat. It is rapidly converted into a purple colouring-matter, which is found to be the true mauve. Indeed, Runge's blue is so prone to change into the more stable mauve, that its composition cannot be satisfactorily determined.

Mr. Kay, in January 1860, took out a patent for producing purple-aniline—most absurdly called 'harmaline'—by adding to sulphate of aniline peroxide of manganese, and heating this mixture to 100° Fahr., when the 'harmaline' so produced remained in solution, and was separated from an insoluble deposit. The dissolved colour was precipitated by adding to the solution ammonia in sufficient quantity to neutralise the acid, after which the insoluble colour was washed, dried, and dissolved in methylated alcohol.

In January 1860 Mr. Greville Williams patented the use of permanganate of potassa as a means of oxidising aniline and producing purples and other colours.

At about the same time Dr. D. Price took out a patent for acting on sulphate of aniline by means of the peroxide of lead.

In 1860 Dale and Caro patented the use of chloride of copper, in the proportion of six equivalents to one of a neutral salt of aniline. In place of chloride of copper, a mixture of sulphate of copper and common salt may be used in equivalent proportions. The quantity of water necessary to dissolve the mixture is added, and the whole is then boiled till a precipitate appears, which contains the colouring-matter. At the expiration of three or four hours the process is completed. The precipitate is collected on a filter, and washed with a solution of soda or carbonate of soda so long as the washings contain chlorides. The residue is then extracted with boiling water, so long as anything dissolves. The solutions thus obtained are filtered, and precipitated with a small quantity of soda or carbonate of soda. The colour thus obtained is ready for use. The matter insoluble in boiling water still contains a violet, which may be extracted by treatment with boiling dilute alcohol in a displacement-apparatus.

On January 12, 1861, another interesting process to obtain aniline-purple was patented by M. A. Girard. Pure aniline-red (known as magenta) is mixed with an equal weight of aniline, and the mixture heated for several hours to 329° Fahr., when the mass is changed to a fine purple colour, requiring only to be mixed with water and hydrochloric acid to remove any aniline or red dye in excess, leaving the purple insoluble; but, on being well washed with water, this becomes soluble in alcohol, acetic acid, wood-naphtha, and boiling water slightly acidulated with acetic acid. The French call this—*Violet Impérial.* See ANILINE.

MAZÉAGE. The French name for a process identical with our Refinery.

MEADOW-ORE is bog-iron ore. See IRON.

MEASURES, WEIGHTS, and **COINS.** See WEIGHTS AND MEASURES.

MEATS, PRESERVED. The interest which has of late attached to the subject of such meats warrants us in bringing under examination the principles and practice on which this important branch of industry is based. The art itself is of modern invention, and differs in every respect from the old or common modes of preserving animal food. These, as is well known, depend upon the use of culinary salt, saltpetre, sugar, or similar substances.

Our remarks will not apply solely to raw or uncooked meats; but the practical bearing of meat-preserving really points to those which are, more or less, cooked or preserved.

The first successful attempt at the preservation of unsalted meats is of French origin, and due to the inventive skill of M. Appert. This gentleman, so long ago as the year 1810, received from the Board of Arts and Manufactures of Paris the sum of 12,000 francs for his discovery of a mode of preserving animal and vegetable substances; the results of which had been then amply attested by a prolonged experience in the French navy. Shortly after this period Appert induced a Mr. Durant to visit London, for the purpose of taking out a patent; and this was accordingly done towards the end of the year 1811. In this patent, however, the claims were ridiculously wide; so much so, that the patent-right was subsequently infringed with impunity. The claims included all kinds of fruit, meat, and vegetables, when subjected to the action of heat in closed vessels, more or less freed from air. As, however, the Society of Arts in London had presented in 1807 a premium to a Mr. J. Suddington, for 'a method of preserving fruit without sugar for house or sea stores'—which method is exactly the same as that of M. Appert—the validity of Durant's patent was at once called in question. Nevertheless, so satisfactory were the results when applied to animal food, or mixed provisions, that the patent was eventually purchased from Durant by Messrs. Donkin, Hall, and Gamble; and the firm, thus established, became at once the sole manufacturers of preserved meats in this country. The process of Appert was, however, extremely defective in a manufacturing point of view. Nothing but glass bottles were to be used for containing the meats, and M. Appert remarks: 'I choose glass for this purpose, as being the most impenetrable to air, and have not ventured to make any experiment with a vessel made of any other substance.' Of course the fragility of this material, and the great difficulty of hermetically sealing the bottles with corks, threw impediments in the way of the process as a commercial undertaking. Nor was it until after a long series of experiments that Messrs. Don-

kin, Hall, and Gamble were able to overcome the primary difficulties of this invention, and produce provisions successfully preserved in tin-plate vessels.

The process of Appert certainly does not depend upon the exclusion of oxygen from the provisions he preserved, nor is this principle included in the improved process still practised by the firm of Gamble. Appert seems to have had a doubt as to the sufficiency of the oxygen theory, for he tells us that, 'fire has a peculiar property, not only of changing the combination of the constituent parts of vegetable and animal productions, but also of retarding, for many years at least, if not of destroying altogether, the natural tendency of these same products to decomposition.' And this opinion is confirmed from many startling facts, which cannot be reconciled to the supposition that oxygen is the sole or even principal agent of decomposition. Thus milk, which has been merely scalded, will keep much longer from the effects of this process, even though freely exposed to, or purposely impregnated with, oxygen gas. Now the method of Appert, as improved by Gamble, is to render the albumen of the meat or the vegetable insoluble, and therefore scarcely if at all, susceptible of the action of atmospheric oxygen. By this means the total exclusion of air from the tin cases is rendered unnecessary, for even if a small quantity of air remain in the case, it will exert no more influence than happens to a piece of coagulated albumen, or hard boiled white-of-egg, which, as is well known, may be exposed to the air for years without sensible alteration, though in its uncoagulated state it immediately putrefies. It appears, therefore, that the essential characteristics of Gamble's process may be referred not to the exclusion of air, but to the thorough coagulation of the albumen. The heat employed also destroys all organic germs that may be present, and thus prevents their development. In this process, the meat, more or less cooked, is placed, with a quantity of gravy, in a tin vessel, capable of being hermetically sealed with solder; it is then heated, for some time, in a bath of muriate of lime, and the aperture neatly soldered up. After this it is again exposed to the action of the heated bath for a period, which varies with the size and nature of the contents of the vessels; and to prove that this latter operation is really the most important of the whole, it sometimes happens that cases which have begun to decompose are opened, resoldered, and again submitted to the muriate-of-lime bath, with the most perfect success, as regards the ultimate result.

Although by no means free from occasional failures and certainly requiring improvement, the system of Gamble has in practice worked well; and provisions have been kept in this way, for a long period of years, without the slightest alteration in their particular qualities.

Mr. Goldner, some few years ago, adopted the idea originally conceived by Sir Humphry Davy, of enclosing cooked provisions in a complete vacuum. For this purpose the provisions, slightly cooked on the surface, were enclosed in canisters, similar to those of Gamble, but stronger, and provided with a small opening in the cover. At this moment a slight condensation was effected by the application of a cold and damp rag or sponge, and simultaneously with this the small opening was soldered up. In theory, nothing could seem better adapted to insure success; but, the practical working of the invention afforded anything but a satisfactory result. Nor is there much difficulty in conceiving how this may arise, as in the first place the application of a sudden heat to non-conducting materials, is almost certain to give rise to that peculiar condition by which the interior of the meat will be as thoroughly protected from the effect of heat as if no heat were applied. Hence, even though steam in abundance may issue from the small opening in the cover, this is no proof that the meat in the centre of the vessel is even warmed; and still less does it warrent the supposition that the soluble albumen is thoroughly coagulated; and without which, as we have stated, preservation is scarcely possible.

Redwood's Process.—This process, invented by Professor Redwood, consists in the immersion of fresh meat in melted paraffin, at a temperature of 240° Fahr. (115° Centigrade), for a sufficient time to effect a concentration of the juices of the meat and the complete expulsion of air; after which the meat, in its condensed state, is covered with an external coating of paraffin, by which air is excluded and decomposition prevented.

The concentration of the juices may thus be carried to any required extent. If the meat is to be kept in hot climates its weight should be reduced by evaporation to about one-half, in which state it will contain all the nutriment of twice its weight of fresh meat, the portion driven off by evaporation consisting only of water. Thus prepared it will be fully cooked (by the heat applied in the process), and it may be eaten without further preparation, but it will also be applicable for the preparation of a variety of made-dishes, including stews, hashes, soups, gravies, etc. For cold climates a less amount of heating and concentration will suffice, so that the meat may retain its original juicy condition, and, when further cooked, present the appearance, and possess all the characters, of fresh unpreserved meat.

The paraffin used in the process is a perfectly innocuous substance; it is entirely free from taste and smell, and is not subject to change from keeping. It may be removed from the surface of the meat by putting the latter into a vessel containing boiling water, when the paraffin as it melts will rise to the surface of the water, and may be taken off in a solid cake when cool, while, at the same time, the meat will become softened and prepared for cooking in any suitable way.

Messrs. [illegible] stated from long experience that if the meat could be kept in a hot room at a temperature of about 100° Fahr. for eight or ten days without change, it would keep for any length of time in any climate, and they are accustomed to submit their preserved provisions to this method of testing before sending them out. It was found, however, that although meat preserved by Prof. Redwood's process would keep for a year or more in the temperate zone, it soon became tainted in tropical regions.

Mr. Richard Jones, in the Society of Arts' "Journal" for January 31, 1873, describes a process carried out by him. He states that the tins are filled with the raw material and placed in a bath, either of boiling water or of chloride of calcium. Before being immersed in the liquid, they are attached, by means of a tube soldered to the cover, and passed to a pipe communicating with a vacuum chamber. On the tins being attached and the tap opened, all the air from the tins is drawn into it. They are then immersed in the liquid at a low temperature, which is gradually raised, if chloride of calcium is used, to 270° Fahr., and the meat is exposed to this heat for a period varying from one to two hours.

Numerous other processes have been employed, most of them partaking in some respects of the characters of one or the other of those described. It cannot, however, be said that any of them have been entirely successful. The chemical processes in all cases impart some peculiar flavour to the meat; and the meat preserved by cooking or partially cooking it in tins was not palatable, being in most cases overcooked in the process. The preservation of fish and vegetables has been carried out with more efficiency.

MEDALS. A piece of metal, usually of gold, silver or bronze, impressed as coins are, but not intended to serve the same purposes as coins. They are made to commemorate some great event in the history of a people, or to perpetuate the memory of some one who has in some way rendered himself illustrious, or they may be for the purpose of giving distinction to merit. The ancients, who produced many excellent examples of the medallist's artistic skill, struck their medals with a hammer; the moderns now use the coining press. Upon the medals produced in modern times the utmost art has been bestowed, and some of them are very beautiful. The late Mr. Wyon, of the Royal Mint, produced during his life-time many medals which may be regarded as superior examples of the medallist's art. Medalets are small medals, often used in Catholic countries, impressed with figures of the saints. Medallions were a larger kind of medals struck as gifts by the Roman emperors. The process of producing a medal is as follows:—

A block for a die being forged, steel of an uniform texture and hard being selected, it is forged, softened by annealing, and the face and shank for the collar turned. The design sketched, the die-sinker proceeds to cut away those parts of the greatest depth by means of small chisels; the more minute details are taken out by gravers, chisel-edged, and pointed steel tools fitted into wood handles very short, and to fit the palm of the hand. As the work proceeds, proofs are taken in wax; when defective in form, the drawing is corrected, and when deficient in relief, it is sunk deeper. It will of course be borne in mind that what will be relief in the medal is hollow in the die. The lettering is introduced by means of small letter-punches. Then follows the hardening of the die, a stage in the process the most critical, as a defect in the steel will at once be made apparent thereby, and the labour of months rendered useless in a few minutes. If the die survives this, it has only another risk, viz. the making of a "hub," or copy of the die in steel, and used for the production of the duplicate copies of the die. The danger in this case arises from the want of uniformity of hardness. [illegible] the portion of the die [illegible] and become [illegible].

Medal-making, or stamping, is thus carried on:—The press consists of a large and fine-threaded screw, to the top of which a lever is attached horizontally. The bed of the press is fitted with screws to secure the die in its place; when this is done the collar which gives the thickness of the medal is fitted on. The die forming the reverse of the medal is attached to the screw, and a blank or piece of metal cut out to form the medal, is then introduced. Motion is imparted to the lever, which operates on the screw; a blow is given, and if the impression is not deep, a medal is produced; but if deep, repeated blows are given to bring the impression up. When bronze or silver is the material of which the medal is to be produced, as many as 20 or even 20 blows are necessary. The medal is then taken out of the press, the edge turned, and the operation is complete.

By 'collar die' is meant that portion which gives the thickness to the medal or coin to be struck. All medal-dies are of three parts, viz. the obverse, reverse, and collar. The smaller class of dies are cut in steel entirely; the larger dies for brass medals and other purposes are made of [illegible] with steel in [illegible]. When inscriptions occur, the die is what is called 'collared' or [illegible], and the steel follows the same in a parallel [illegible]. See [illegible].

MEEKRAP. The Dutch commercial name for Madder-root. See MADDER.

MEERSCHAUM (Ger. *Sea-froth*, Eng.; *Écume de Mer*; *Magnésite carbonatée silicifère*). This is a white mineral, of a somewhat earthy appearance, always soft, and dry to the touch, and adhering to the tongue. Specific gravity 1·2 to 1·6; when moist, nearly 2·0; absorbs water by immersion; fuses with difficulty at the blowpipe into a white enamel; and is acted upon by acids. It consists, when pure, of silica 60·87, magnesia 27·80, water 11·33. An analysis by Berthier gave, silica 50, magnesia 25, water 25. It occurs in veins or kidney-shaped masses among rocks of serpentine, chiefly at Eskishehr in Asia Minor; also in the island of Negropont, Hrubschitz in Moravia, [illegible] in the [illegible] of [illegible] [illegible], at Baldissero in Piedmont, &c.

When first dug up, it is soft, and lathers like soap; on which account, and from its absorbing grease, it is used by the Tartars in washing their linen. The well-known Turkey tobacco-pipes are carved from it. The bowls of the pipes, when imported into Germany, are prepared for sale by soaking them first in tallow, then in wax, and finally by polishing them with shave-grass.

The most extensive deposits of meerschaum in Asia Minor lie near [illegible] [illegible] [illegible] [illegible], in a direct way [illegible] from the town of Eskishehr, the ancient Dorylæum, the population of which, about [illegible],000 Armenians and Turks, is mostly engaged in the working and sale of it. It is brought from the galleries of pits [illegible] to [illegible] metres in depth. In one pit there will be [illegible] to [illegible] miners, [illegible] [illegible] [illegible] a [illegible] share the profits from the minerals. The size of the stones varies and is generally very irregular, varying from that of a nut to a cubic foot or more. The mineral, fresh from the ground, is covered about a finger thick with red clay earth, and is so soft that one can cut it with a knife. Its preparation is slow and troublesome. After removal of the earth, it is dried 5 to 6 days in the sun, or 8 to 10 in a [illegible] chamber; then it is cleaned again and polished with wax. Then the different kinds, of which there are ten, are sorted and carefully packed with wool in boxes. By cleaning and drying, the stones lose about two-thirds of their weight and volume. The largest quantities are sent to Austria (Vienna) and Germany, and the annual export is about [illegible],000 to [illegible],000 boxes, representing a value of 1,200,000 francs. The Turkish Government imposes a tax of 12½ per cent. at the place of extraction of the raw material, and a further tax of 12½ per cent. on the sale.

MELAMINE ([illegible]), an alkali produced from melam under the influence of boiling potash. It is isomeric with cyanamide, from which it may be produced by the action of heat. Melam is obtained by the distillation of sulphocyanide of ammonium.

MELANITE. Eng. and Fr.; *[illegible]*, Ger. See [illegible].

MELLITIC ACID, which is associated with alumina in the honey-stone mineral, crystallises in small colourless needles, is without smell, of a strongly acid taste, permanent in the air, soluble in water and alcohol, is also in boiling concentrated sulphuric acid, but is decomposed by hot nitric acid, [illegible] [illegible] [illegible] [illegible] of oxygen. It is sublimed at a red heat, without the production of any empyreumatic oil. See WATTS'S Dictionary of Chemistry.

MELLONE. Syn. *Mellon*, is a compound of carbon and nitrogen, discovered by M. Liebig by heating bi-sulpho-cyanide of mercury. The mellone remains at the bottom of the retort under the form of a yellow powder. See WATTS'S Dictionary of Chemistry.

MELTING POTS, or *Crucibles*. The best crucibles are formed from a pure fire-clay, mixed with finely-ground cement of old crucibles and a portion of black lead or graphite. Some powdered coke may be mixed with the [illegible]. The clay should be prepared in a similar way as for making pottery ware. The vessels, after being formed, must be slowly dried, and then properly baked in the kiln. Crucibles formed of a mixture of 8 parts of raw [illegible] Stourbridge clay and cement, 5 of coke and 4 of graphite, have been found to stand 70 meltings of 70 pounds of cast steel, in the Royal Berlin Foundry. Such crucibles resisted the greatest possible heat that could be produced, in which even wrought iron was melted, equal to 150° of Wedgwood, and bore sudden cooling without cracking.

Another composition for brass-founding crucibles is the following:—2 Stourbridge clay; ¼ burned-clay cement; ⅛ coke-powder; ⅛ pipe-clay. The pasty mass must be compressed in moulds. The Hessian crucibles from Great Almerode and Epterode are made from a fire-clay which contains a little iron, but no lime; it is incorporated with siliceous sand. The dough is compressed in a mould, dried and strongly kilned. They stand saline and leaden fluxes in assaying operations very well; are rather porous on account of the coarseness of the sand, but are thereby less apt to crack from sudden heating or cooling. They melt under the fusing-point of bar-iron. Beaufay in Paris has lately succeeded in making a tolerable imitation of the Hessian crucibles with a fire-clay found near Namur in the Ardennes.

Berthier has published the following elaborate analyses of several kinds of crucibles:—

	Hessian	Beaufay	English for cast steel	St. Etienne for cast steel	Glass-pots at Nemours	Bohemian glass-pots	Glass-pots of Creusot
Silica . .	70·9	64·6	63·7	65·2	67·4	68·0	68·0
Alumina .	24·8	33·4	20·7	25·0	32·0	29·0	28·0
Oxide of iron	3·8	1·0	4·0	7·2	0·8	2·2	2·0
Magnesia .	trace	...	...	trace	trace	0·5	trace
Water . .	...	...	10·3[1]	...	...	...	1·0

Wurzur states the composition of the sand and clay in the Hessian crucibles as follows:—

Clay; silica 10·1; alumina 65·4; oxides of iron and manganese 1·2; lime 0·3; water 23
Sand; „ 95·6; „ 2·1; „ „ 1·5; „ 0·8

The composition of some of the best varieties of fire-clay, as deduced from the analyses of Berthier and Salvetat, is given in the following table:—

Dried at 212°	Great Almerode Hessian crucible-clay		Beaufay's Department of Ardennes	Brierley Hill, near Stourbridge		Schierdorf, near Passau
	Berthier	Salvetat	Berthier	Berthier	Salvetat	Salvetat
Hygrometric water	...	0·43	...	...	...	0·50
Combined water .	15·2	14·00	19·0	10·3	17·34	16·50
Silica . . .	46·5	47·50	52·0	63·7	45·25	45·79
Alumina . .	34·9	34·37	27·0	20·7	28·77	28·10
Oxide of iron .	3·0	1·24	2·0	4·0	7·72	6·55
Lime . . .	...	0·50	...	...	0·47	2·00
Magnesia . .	...	1·00	...	...	...	...
Alkalis . .	...	trace	...	...	...	...

Quoted from Knapp's 'Technology.'

Mr. C. Cowper has analysed the clays used at Birmingham for glass-pots. His results were as follow:—

	In the dry state		In the ordinary state	
	Best Stourbridge pot clay	Clay from Monmouth	Best Stourbridge pot clay	Clay from Monmouth
Silica	70·6	80·1	63·3	75·3
Alumina . . .	25·9	17·9	23·3	16·8
Oxide of iron . .	2·0	1·0	1·8	1·0
Carbonate of lime .	1·5	1·0	1·3	0·9
„ magnesia .	trace	...	trace	...
Water	...	...	10·0	6·0
Total . .	100·0	100·0	100·0	100·0

Black-lead crucibles are made of two parts of graphite and one of fire-clay, mixed with water into a paste, pressed in moulds, and well dried, but not baked hard in the kiln. They bear a higher heat than the Hessian crucibles, as well as sudden changes of temperature; have a smooth surface, and are therefore preferred by the melters of gold and silver. This compound forms excellent small or portable furnaces.

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[1] This crucible had been analysed before being baked in the kiln

The crucibles from Passau or Ipser are made from one part plastic clay from Schildorf, and from two to three parts of an impure graphite, which, according to Berthier's analysis, consists of—

Carbon	34
Silica	41
Alumina	15
Oxide of iron	8
Magnesia, water	2
	100

Berthier has examined the crucibles of different districts; his results are as follow:—

	Silica	Alumina	Oxide of iron	Magnesia
Crucibles from Gros Almerode	70·9	24·8	3·8	...
" Paris	64·6	34·4	1·0	...
" Saveignies (Beaufay's)	72·3	19·5	3·9	...
" England (for steel)	71·0	23·0	4·0	...
" St. Etienne (for steel)	65·2	25·0	7·2	...
Glass pots from Nemours	67·4	32·0	0·8	...
" Bohemia	68·0	29·0	2·2	0·5

Mr. Anstey describes his patent process for making crucibles as follows:—Take two parts of fine-ground raw Stourbridge clay, and one part of the hardest gas-coke, previously pulverised, and sifted through a sieve of one-eighth of an inch mesh (if the coke is ground too fine, the pots are very apt to crack). Mix the ingredients together with the proper quantity of water, and tread the mass well. The pot is moulded by hand upon a wooden block, supported on a spindle which turns in a hole in the bench; there is a gauge to regulate the thickness of the melting pot, and a cap of linen or cotton placed wet upon the core before the clay is applied, to prevent the clay from sticking partially to the core, in the taking-off; the cap adheres to the pot only while wet, and may be removed without trouble or hazard when dry. He employs a wooden bat to assist in moulding the pot; when moulded, it is carefully dried at a gentle heat. A pot dried as above, when wanted for use, is first warmed by the fire-side, and is then laid in the furnace with the mouth downwards (the red cokes being previously damped with cold ones in order to lessen the heat); more coke is then thrown in till the pot is covered, and it is now brought gradually to a red heat. The pot is next turned and fixed in a proper position in the surface, without being allowed to cool, and is then charged with cold iron, so that the metal, when melted, shall have its surface a little below the mouth of the pot. The iron is melted in about an hour and a half, and no flux or addition of any kind is made use of. A pot will last for fourteen or even eighteen successive meltings, provided it is not allowed to cool in the intervals; but if it is cool, will probably crack. These pots, it is said, can bear a greater heat than others without softening, and will, consequently, deliver the metal in a more fluid state than the best Birmingham pots will.

The Cornish crucible has been long known, and valued for all assaying purposes. They are prepared in large quantities for the ordinary assays made in the county, and are exported in considerable numbers. The base of these crucibles is the Poole and Stourbridge clay, which is mixed with a certain proportion of sand obtained from St. Agnes, and ground pots.

Dr. Percy has favoured us with his analysis of the Cornish crucible:—

Silica	72·29
Alumina	25·32
Peroxide of iron	1·07
Lime	0·38
Magnesia	trace
Potash.	1·14

MENACCANITE. An ore of *titanium*, found in the bed of a rivulet which flows into the valley of Menaccan in Cornwall.

MERCURY, or *Quicksilver*. This metal is distinguished by its fluidity at common temperatures; its specific gravity = 13·6; its silver-blue lustre; and its extreme mobility. A cold of 39° below zero of Fahrenheit, or −40° Cent., is required for its congelation, in which state its density is increased in the proportion of 10 to 9, or it becomes of specific gravity 15·0. At a temperature of 662° F. it boils and distils off in an elastic vapour of specific gravity 6·976, which, being condensed by cold, forms purified mercury.

Mercury combines with great readiness with gold, silver, zinc, tin, and bismuth, forming, in certain proportions, fluid solution of these metals. Such mercurial alloys are called *amalgams*. This property is extensively employed in many arts; as in extracting gold and silver from their ores; in gilding, plating, making looking-glasses, &c. (See AMALGAM.) Humboldt estimates at 16,000 quintals, of 100 lbs. each, the quantity of mercury annually employed in the treatment of the ores of the mines of New Spain; three-fourths of which came from European mines.

The mercurial ores belong principally to the following four species:—

1. *Native quicksilver.*—It occurs in most of the mines of the other mercurial ores, in the form of small drops attached to the rocks, or lodged in the crevices of other ores.

2. *Native silver amalgam.*—It has a silver-white colour, and is more or less soft, according to the proportion which the mercury bears to the silver. Its density is sometimes so high as 14. A moderate heat dissipates the mercury, and leaves the silver. Klaproth states its constituents at silver 36, and mercury 64, in 100; but Cordier makes them to be, 27½ silver and 72½ mercury. It occurs crystallised in the cubic system. It has been found in the territory of Deux-Ponts; at Rozenau and Niderstana, in Hungary, in a canton of Tyrol, at Sala in Sweden, at Kolyvan in Siberia, and at Allemont in Dauphiny; in small quantity at Almaden in Spain, and at Idria in Carniola. In the rich silver mines of Arqueros, near Coquimbo, this mineral occurs, having the composition, silver 86·49, mercury 13·51. This is the *arquerite* of Domeyko. By the chemical union of the mercury with the silver, the amalgam, which should by calculation have a specific gravity of only 12·5, acquires that of 14·11. See AMALGAM; ARQUERITE.

3. *Sulphide of Mercury*, commonly called *Cinnabar*, is a red mineral of various shades; burning at the blowpipe with a blue flame, volatilising entirely with the smell of burning sulphur, and giving a quicksilver coating to a plate of copper held in the fumes. Even the powder of cinnabar rubbed on copper whitens it. Its density varies from 6·9 to 10·2. It becomes negatively electrical by friction. Analysed by Klaproth, it was found to consist of mercury 84·5, sulphur 14·75. Its composition, viewed as a bisulphuret of mercury, is, mercury 86·2, sulphur 13·8. Its chief localities are Idria, in Carniola; Almaden, in Spain; and New Almaden, in California. It is found also at Wolfstein, in Rhenish Bavaria; in Saxony, in the Hartz; in Carinthia, Styria, Bohemia, Hungary, and Tuscany; in the Ural and Altai; in China, Japan, Queensland, Mexico, and Peru. See CINNABAR.

A *bituminous sulphide of mercury* appears to be the base of the great exploration of Idria; it is of a dark liver-red hue, and of a slaty texture, with straight or twisted plates. It exists in large masses in the bituminous schists of Idria. M. Berard mentions also the locality of Münster-Appel, in the duchy of Deux-Ponts, where the ore includes impressions of fishes, curiously spotted with cinnabar.

The compact variety of Idria ore seems very complex in composition, according to the following analysis of Klaproth:—Mercury, 81·8; sulphur, 13·75; carbon, 2·3; silica, 0·65; alumina, 0·55; oxide of iron, 0·20; copper, 0·02; water, 0·73; in 100 parts. M. Berard mentions another variety from the Palatinate, which yields a large quantity of bitumen by distillation; and it was present in all the specimens of these ores analysed by Dr. Ure for the German Mines Company. At Idria and Almaden the sulphides are extremely rich in mercury.

4. *Chloride of mercury*, or *Native Calomel*, commonly called *Horn-mercury*. This mineral, which is very rare, occurs in very small crystals of a pearl-grey or greenish-grey colour, or in small nipples which stud, like crystals, the cavities, fissures, or geodes among the ferruginous gangues of the other ores of mercury. It is brittle, and entirely volatile at the blowpipe; characters which distinguish it from horn silver. See CALOMEL.

Ores of mercury are found in rocks of almost every geological age. At Almaden, in Spain, they occur in deposits at the contact of Silurian slates with a metamorphic rock locally called *fraylesca*. At Ripa, in Tuscany, the veins traverse mica-slate. The deposits at Deux-Ponts, or Zweibrücken, in the Palatinate, are said to be in red sandstones of Permian age, and in the *zechstein*, or magnesian limestone. At Idria, in Carniola, the ores are disseminated through shales and black compact limestones of the Jurassic period; and at New Almaden, in California, the rocks containing the cinnabar belong to the Cretaceous period. Cinnabar is now in course of formation in some of the siliceous deposits thrown down from the hot springs of California and Nevada.

The great mines of Idria in Friuli, in the county of Goritz, were discovered in 1497, and the principal ore mined there is the bituminous cinnabar. The workings of this mine have been pushed beyond the depth of 280 yards. The product in quicksilver might easily amount annually to 6,000 metrical quintals = 600 tons British; but, in order to uphold the price of the metal, the Austrian Government has restricted the production to 150 tons. The memorable fire of 1803 was most disastrous to these mines. It was extinguished only by drowning all the underground workings. The sublimed mercury in this catastrophe occasioned diseases and nervous tremblings to more than 900 persons in the neighbourhood.

The mines of Almaden according to Pliny supplied the Greeks with red cinnabar 700 years before the Christian era; and Rome, in his time, annually received 700,000 pounds from the same mines. Since 1827, the Almaden mines have produced 22,000 cwts. of mercury every year, with a corps of 700 miners and 200 smelters; and, indeed, the veins are so extremely rich, that though they have been worked pretty constantly during so many centuries, the mines have hardly reached the depth of 330 yards, or something less than 1,000 feet. The lode actually under exploration is from 14 to 16 yards thick, and it becomes thicker still at the crossing of the veins. The ores yield in their smelting works only 10 per cent. upon an average; but there is no doubt, that nearly one-half of the quicksilver is lost, and dispersed in the air, to the great injury of the workmen's health, in consequence of the barbarous apparatus of aludels employed in its sublimation; an apparatus which has remained without any material change for the better since the days of the Moorish dominion in Spain. M. Le Play, who published, in the *Annales des Mines*, his *Itinéraire* to Almaden, says, that the mercurial contents of the ores are *notablement plus élevées* than the product.

These veins extend all the way from the town of Chillon to Almadenejos. Upon the borders of the streamlet Balde Alogues, a black slate is also mined which is abundantly impregnated with metallic mercury.

These celebrated mines, near to which lie those of *Las Cuebas* and of *Almadenejos*, after having been the property of the religious knights of *Calatrava*, who had assisted in expelling the Moors, were farmed off to the celebrated Fugger merchants of Augsburg; and afterwards explored on account of the government, from the date of 1645. Their produce was, till very lately, entirely appropriated to the treatment of the gold and silver ores of the New World.

The mines of the Palatinate, situated on the left bank of the Rhine, though they do not approach in richness and importance to those of Idria and Almaden, merit, however, all the attention of the government that farms them out. They are numerous, and varied in geological position. Those of Drey-Königszug, at Potzberg, near Kussel, deserve particular notice. The workings have reached a depth of more than 220 yards; the ore being a sandstone strongly impregnated with sulphuret of mercury. The produce of these mines is estimated at about 30 tons per annum.

There are also in Hungary, Bohemia, and several other parts of Germany, some inconsiderable mines of mercury, the total produce of which is valued at about 30 or 40 tons on an average of several years.

The mines of Huancavelica, in Peru, are the more interesting, as their products are directly employed in treating the ores of gold and silver which abound in that portion of America. These quicksilver mines have been explored since 1570, the actual produce of the explorations being, according to Helms, about the beginning of this century, from 170 to 180 tons per annum.

In 1782 recourse was had by the South American miners to the mercury extracted in the province of Yun-nan, in China.

The mercurial mines of California are thus described by Dr. Tobin:—

'That part of California where I have been residing, and that which I have just visited, consists of three long ranges of trap mountains, with two wide valleys dividing them, the valley of the San Joaquin, and the valley of Santa Clara. Near this last place are the quicksilver mines of New Almaden, where I have been working. The matrix of the cinnabar ore is the same trap of which the mountain ranges are composed, and as yet only one great deposit of this ore has been found, though *traces* of quicksilver ores have been discovered in other places. The ores are composed solely of sulphuret of mercury (averaging 36 per cent.), red oxide of iron, and silica; and, had the mine been properly worked from the commencement, almost any quantity of ore might be extracted; it now, however, more resembles a gigantic rabbit-warren than a mine. Its greatest depth is about 150 feet, and the weekly extraction of ores varies from 100 to 150 tons. 16 cylinders are at work, producing 1,400 to 1,500 lbs. daily.

Mr. Russell Bartlett, the United States Commissioner on the Mexican and United States Boundary Question, who visited California in 1853, states that the quantity of quicksilver produced annually at New Almaden, exceeds 1,000,000 lbs. During the year 1853 the total exports from San Francisco amounted to 1,350,000 lbs., valued at 683,189 dollars. All this, together with the large amount used in California, was the product of the New Almaden mine in the Santa Clara county, 12 miles from the town of San José, which is 54 miles from the city of San Francisco. The working of the mine was begun in the year 1846–7 by an English company, but for some reasons was not profitable; in 1849–50 it fell into American hands.

The analysis compared with that of the Old Almaden ore furnished the following results to Mr. Bealey ('Quarterly Journal of Chemical Society,' vol. iv.):—

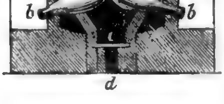
	New Almaden	Old Almaden
Mercury	60·90	37·79
Sulphur	11·29	16·22
Iron	1·23	10·36
Lime	1·40	35·12 silica and alumina.
Alumina	0·61	—
Magnesia	0·49	—
Silica	14·41	—
Loss	·67	·51
	100·00	100·00

Production of Quicksilver in California.

	1868	1869	1870	1871	1872	1873
	flasks	flasks	flasks	flasks	flasks	flasks
New Almaden Mine	25,600	17,000	14,000	18,763	17,753	12,000
New Idria Mine	12,300	10,450	10,000	9,227	8,597	7,600
Redington Mine	8,700	5,000	4,546	2,128	2,456	4,200
Sundry other mines	2,100	1,150	1,000	1,763	1,500	4,800
Total	48,700	33,600	29,546	31,881	30,306	28,600

Metallurgy of Quicksilver.—The metallurgic treatment of the quicksilver ores is tolerably simple. In general, when the sulphuret of mercury, the most common ore, has been pulverised, and sometimes washed, it is introduced into retorts of cast iron, sheet iron, or even stoneware, in mixture with an equal weight of quicklime. These retorts are arranged in various ways.

Prior to the 17th century, the method called *per descensum* was the only one in use for distilling mercury; and it was effected by means of two earthen pots adjusted over each other. The upper pot, filled with ore, and closed at the top, was covered over with burning fuel; and the mercurial vapours expelled by the heat, passed down through small holes at the bottom of the pot, to be condensed in another vessel placed below. However convenient this apparatus might be, on account of the facility of transporting it, wherever the ore was found, its inefficiency and the losses it occasioned were eventually recognised. Hence, before 1635, some smelting works of the Palatinate, had given up the method *per descensum,* which was, however, still retained in Idria; and they substituted for it the furnaces called *galleries.* At first earthenware retorts were employed in these furnaces; but they were soon succeeded by iron retorts. In the Palatinate this mode of operating is still in use. At Idria, in the year 1750, a great distillatory apparatus was established for the treatment of the mercurial ores, in imitation of those which previously existed at Almaden, in Spain, and called *aludel-furnaces.* But, since 1794, these aludels have been suppressed, and new distillatory apparatus have been constructed at Idria, remarkable only for their magnitude; exceeding, in this respect, every other metallurgic erection.

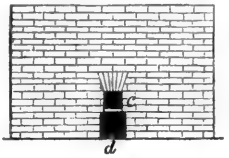


There exist, therefore, three kinds of apparatus for the distillation of mercury: 1, the furnace called a *gallery;* 2, the furnace with *aludels;* and 3, the *large apparatus* of Idria. We shall describe each of these briefly, in succession.

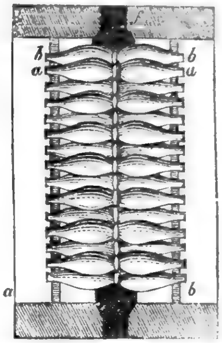
1. *Furnace called Gallery of the Palatinate.*—The construction of this furnace is disposed so as to contain four ranges, *a a′*, *b b′*, of large retorts, styled cucurbits, of cast iron, in which the ore of mercury is subjected to distillation. This arrangement is shown in *fig.* 1432, which presents a vertical section in the line *a b* of the ground plan, *fig.* 1433. In the ground plan, the roof *e e*, of the furnace (*fig.* 1432) is supposed to be lifted off,

in order to show the disposition of the four ranges of cucurbits upon the grate *c f*, *figs.* 1432, 1434, which receives the pit-coal employed as fuel. Under this grate extends an ash-pit. *d*, *fig.* 1434, which exhibits an elevation of the furnace, points out this ash-pit, as well as one of the two doors *c*, by which the fuel is thrown upon the grate *c f*. Openings *e e* (*fig.* 1432) are left over the top arch of the furnace, whereby the draught of air may receive a suitable direction. The grate of the fireplace extends over the whole length of the furnace, *fig.* 1433, from the door *c* to the door *f*, situated at the opposite extremity. The furnace called *gallery* includes commonly 30 cucurbits, and in some establishments even 52. Into each are introduced from 56 to 70 pounds of ore, and 15 to 18 pounds of quicklime, a mixture which fills no more than two-thirds of the cucurbit; to the neck a stoneware receiver is adapted, containing water to half its height. The fire, at first moderate, is eventually pushed, till the cucurbits are red hot. The operation being concluded, the contents of the receivers are poured out into a wooden bowl placed upon a plank above a bucket; the quicksilver falls to the bottom of the bowl, and the water draws over the *black mercury*, for so the substance that coats the inside of the receivers is called. This is considered to be a mixture of sulphide and oxide of mercury. The *black mercury*, taken out of the tub and dried, is distilled anew with excess of lime: after which the residuum in the retorts is thrown away as useless.

1434

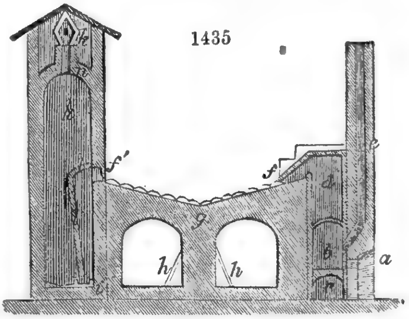


1433

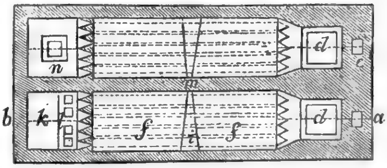


2. *Aludel-furnaces of Almaden.*—*Figs.* 1435 to 1438 represent the great furnaces with aludels in use at Almaden, and anciently in Idria; for between the two establishments there was in fact little difference before the year 1794. *Figs.* 1435 and 1438 present two vertical sections; *figs.* 1436 and 1437 are two plans of two similar furnaces, conjoined in one body of brickwork. In the four figures the following objects are to be remarked: a door *a*, by which the wood is introduced into the fire-place *b*. This is perforated with holes for the passage of air; the ash-pit *c*, is seen beneath. An upper chamber *d*, contains the mercurial ores distributed upon open arches, which form the perforated sole of this chamber. Immediately over these arches, there are piled up in a dome form, large blocks of a limestone, very poor in quicksilver ore; above these are laid blocks of a smaller size, then ores of rather inferior quality, and stamped ores mixed with richer minerals. Lastly, the whole is covered up with soft bricks, formed of clay kneaded with *Schlich*, and with small pieces of sulphide of mercury. Six ranges of aludels or stoneware tubes *f f*, of a pear shape, luted together with clay, are mounted in front of each of the two furnaces on a double sloping terrace, having in its lowest middle line two gutters *t*, *v*, a little inclined towards the intermediate wall *m*. In each range the aludel placed at the line *t m v*, *fig.* 1436, that is to say at the lowest point, *g*. *figs.* 1435, 1438, is pierced with a hole. Thereby the mercury which had been volatilised in *d*, if it be already condensed by the cooling in the series of aludels *f g*, may pass into the corresponding gutter, next into the hole *m*, *fig.* 1436, and after that into the wooden pipes *h h'*, *fig.* 1435, which conduct it across the masonry of the terrace into cisterns filled with water; see *q*, *fig.* 1437, which is the plan of *fig.* 1438.

1435

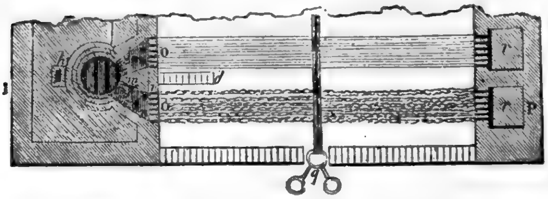


1436



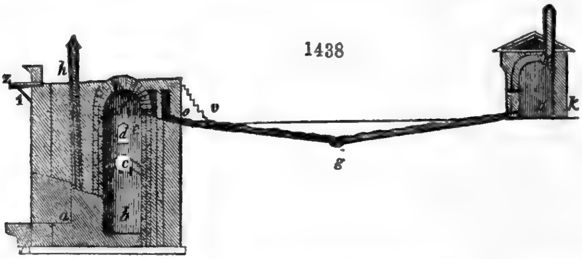
The portion of mercury not condensed in the range of aludels, *f g*, which is the most considerable, goes in the state of vapour into a chamber *k*; but in passing under a partition *l l*, a certain portion is deposited in a cistern *i*, filled with water. The greater

1437



part of the vapours diffused in the chamber *k′* is thereby condensed, and the mercury falls down upon the two inclined planes which form its bottom. What may still exist

1438



as vapour passes into an upper chamber *k′* by a small chimney *n*. On one of the sides of this chamber there is a shutter which may be opened at pleasure from below upwards, and beneath this shutter there is a gutter into which a notable quantity of mercury collects. Much of it is also found condensed in the aludels. These facts prove that this process has inconveniences, which have been tried to be remedied by the more extensive but rather unchemical grand apparatus of Idria.

Details of the Aludel Apparatus.—25 aludels are set in each of the 12 ranges, seen in *figs.* 1437, 1438, constituting 300 pear-shaped stoneware vessels, open at both ends, being merely thrust into one another, and luted with loam. *a*, is the door of the fire-place; *c*, the perforated arches upon which the ore is piled in the chamber *c*, through the door *d*, and an orifice at top; the latter being closed during the distillation; *f f* are vents for conducting the mercurial vapours into two chambers *i*, separated by a triangular body of masonry *m n*; *h* is the smoke-chimney of the fire-place; *o o* are the ranges of aludels, in connection with the chamber *i*, which are laid slantingly towards the gutter *q*, upon the double inclined plane terrace, and terminate in the chamber *h q*; this being surmounted by two chimneys *t*. The mercury is collected in these aludels and in the basins at *q* and *p*, *fig.* 1437. *r* is a thin stone partition set up between the two principal walls of each of the furnaces. *v* is the stair of the aludel terrace leading to the platform which surmounts the furnace; *z* is a gutter for conducting away the rains which may fall upon the buildings, *fig.* 1438.

3. *Great Apparatus of Idria.*—Before entering into details of this laboratory, it will not be useless to state the metallurgic classification of the ores treated in it: 1. The ores in large blocks, fragments, or shivers, whose size varies from a cubic foot to that of a nut. 2. The smaller ores, from the size of a nut to that of grains of dust.

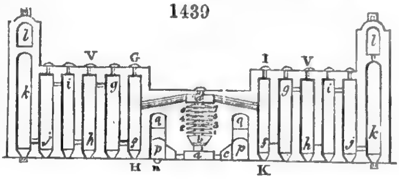
The first class of *large* ores comprises three subdivisions, namely: *a*, blocks of metalliferous rocks, which is the most abundant and poorest species of ore, affording only 1 per cent. of mercury; *b*, the massive sulphide of mercury, the richest and rarest ore, yielding 80 per cent. when it is picked; *c*, the fragments or splinters proceeding from the breaking and sorting, and which vary in value from 1 to 40 per cent.

The second class of small ores comprises: *d*, the fragments or shivers extracted from the mine in the state of little pieces, affording from 10 to 12 per cent.; *e*, the kernels of ore separated on the sieve, yielding 32 per cent.; *f*, the sands and paste called *schlich*, obtained in the treatment of the poorest ores, by means of the stamps and washing tables; 100 parts of this *schlich* give at least 8 of quicksilver.

The general aspect of the apparatus is indicated by *figs.* 1439, 1440, 1441, and 1442.

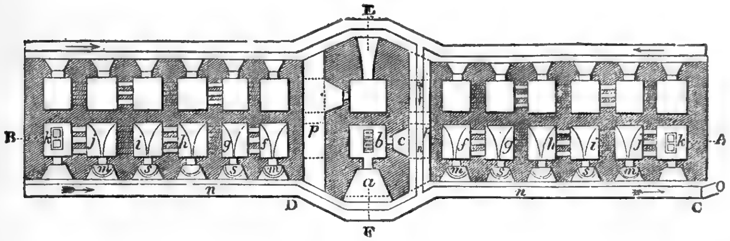
Fig. 1441 represents the exterior, but only one half, which is enough, as it resembles exactly the other, which is not shown. In these three figures the following objects may be distinguished: *figs.* 1439, 1440, *a*, door of the fire-place; *b*, the furnace in which beech-wood is burned mixed with a little fir-wood; *c*, door of the ash-pit, extended beneath; *d*, a space in which the ores are deposited upon the seven arches, 1 to 7, as indicated in *figs.* 1439 and 1442; *e e* brick tunnels, by which the smoke of the fuel and the vapours of mercury pass, on the one side, into successive chambers *f k*.

1439



f g h i j k l are passages which permit the circulation of the vapours from the furnace *a b c d*, to the chimneys *l l*. *Figs.* 1439 and 1440 exhibit clearly the distribution of these openings on each side of the same furnace, and in each half of the apparatus, which is double, as *fig.* 1440 shows; the spaces without letters being in every respect similar to the spaces mentioned below. *Fig.* 1440 is double the scale of *fig.* 1439.

1440

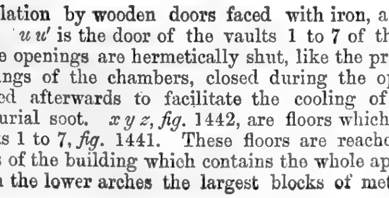


m m', *fig.* 1440, are basins of reception, distributed before the doors of each of the chambers *f k f' k'*. The condensed mercury which flows out of the chambers is conveyed thither. *n n'* is a trench into which the mercury, after being lifted into the basins *m*, is poured, so that it may run towards a common chamber *o*, in the sloping direction indicated by the arrows. *o* leads to the chamber where the mercury is received into a porphyry trough; out of which it is laded and packed up in portions of 50 or 100 lbs. in sheep-skins prepared with alum.

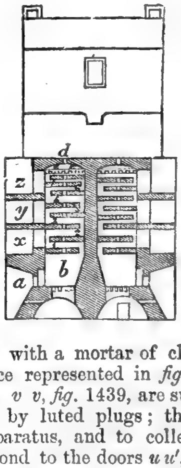
p p', *fig.* 1439, are vaulted arches, through which a circulation may go on round the furnace *a b c d*, on the ground level. *q q'* are the vaults of the upper stories. *r r'*, *fig.* 1441, vaults which permit access to the tunnels *e' e''*, *fig.* 1442.

s s' and *t t'*, *fig.* 1441, are the doors of the chambers *f k* and *f' k'*. These openings are shut during the distillation by wooden doors faced with iron, and luted with a mortar of clay and lime. *u u'* is the door of the vaults 1 to 7 of the furnace represented in *fig.* 1439. These openings are hermetically shut, like the preceding. *v v*, *fig.* 1439, are superior openings of the chambers, closed during the operation by luted plugs; they are opened afterwards to facilitate the cooling of the apparatus, and to collect the mercurial soot. *x y z*, *fig.* 1442, are floors which correspond to the doors *u u'*, of the vaults 1 to 7, *fig.* 1441. These floors are reached by stairs set up in the different parts of the building which contains the whole apparatus.

1441



1442



On the lower arches the largest blocks of metalliferous rock are laid, over these the less bulky fragments are arranged, which are covered with the shivers and pieces of less dimension. On the middle vaults, the small ore is placed, distributed in cylindrical pipkins of earthenware, of 10 inches diameter and 5 inches depth. The upper vaults receive likewise pipkins filled with the sands and pastes called *schlich.*

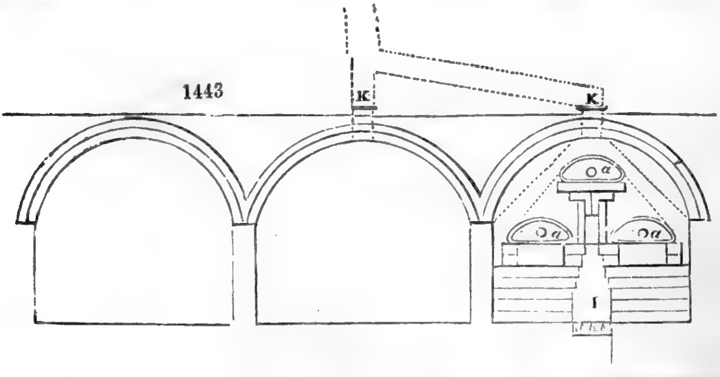
In 3 hours, by the labours of 40 men, the two double sets of apparatus are charged, and all the apertures are closed. A quick fire of beech-wood is then kindled, and when the whole mass has become sufficiently heated, the sulphuret of mercury begins to vaporise; coming into contact with the portion of oxygen which had not been carbonised by combustion, its sulphur burns into sulphurous acid, while the mercury becomes free, passes with the other vapours into the chambers for condensing it, and precipitates in the liquid form at a greater or less distance from the fire-place. The walls of the chambers and the floors, with which their lower portion is covered, are soon coated over with a black mercurial soot, which, being treated anew, furnishes 50 per cent. of mercury. The distillation lasts from 10 to 12 hours; during which time the whole furnace is kept at a cherry-red heat. A complete charge for the two double apparatus consists of from 1,000 to 1,300 quintals of ore, which produce from 80 to 90 quintals of running mercury. The furnace takes from 5 to 6 days to cool, according to the state of the weather; and if to that period be added the time requisite for withdrawing the residuums, and attending to such repairs as the furnace may need, it is obvious that only one distillation can be performed in the course of a week.

It has been long well known, that quicksilver may be most readily extracted from cinnabar, by heating it in contact with quicklime. The sulphur of the cinnabar combines, by virtue of a superior affinity with the lime, to the exclusion of the quicksilver, to form sulphide of calcium, which being fixed, remains in the retort, while the mercury is volatilised by the heat. In a few places, *Hammerschlag*, or the iron cinder driven off from the blooms by the tilting hammer, has been used instead of lime in the reduction of this mercurial ore, whereby sulphurous acid and sulphide of iron are formed.

The modes practised at Almaden and Idria are far from economical; the ores being heated upon open arches, and the vapours attempted to be condensed by enclosing them within brick or stone and mortar walls, which can never be rendered either sufficiently tight or cool.

To obviate all these inconveniences and sources of loss, the proper chemical arrangements suited to the present improved state of the arts ought to be adopted, by which labour, fuel, and mercury might all be economised to the utmost extent. The only apparatus fit to be employed is a series of cast-iron cylinder retorts, somewhat like those employed in the coal-gas works, but with peculiarities suited to the condensation of the mercurial vapour. Into each of these retorts, supposed to be at least one foot square in area, and 7 feet long, 6 or 7 cwts. of a mixture of the ground ore with the quicklime may be easily produced from a measured heap by means of a shovel. The specific gravity of the cinnabar being more than 6 times that of water, a cubic foot of it will weigh more than 3½ cwts.; but supposing the mixture of it with quicklime (when the ore does not contain the calcareous matter itself) to be only thrice the density of water, then 4 cubic feet might be put into each of the above retorts, and still leave 1½ cubic foot of empty space for the expansion of volume which may take

1443



place in the decomposition. The ore should certainly be ground to a moderately fine powder, by stamps, iron cylinders, or an edge-wheel, so that when mixed with quicklime, the cinnabar may be brought into intimate contact with its decomposer, otherwise much of it will be dissipated unproductively in fumes, for it is extremely volatile.

Figs. 1443, 1444, 1445 represent a cheap and powerful apparatus contrived by Dr. Ure at the request of the German Mines Company of London, and which was mounted at Landsberg, near Obermoschel, in the Bavarian Rhein-Kreis.

1444

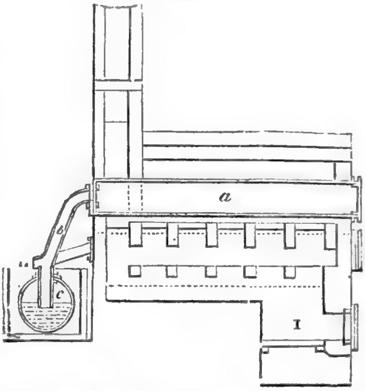
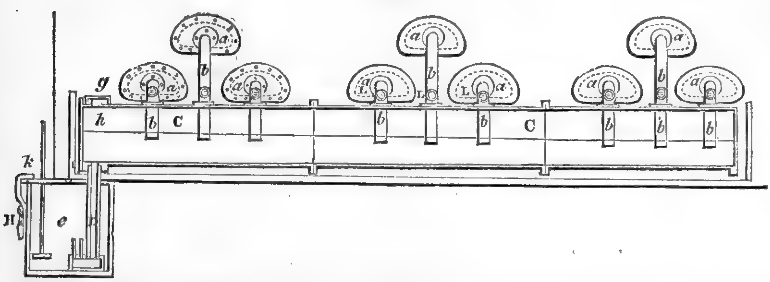


Fig. 1440 is a section parallel to the front elevation of three arched benches of retorts, of the size above specified. Each bench contains 3 retorts of the form represented by *a a a*. I is the single fire-place or furnace, capable of giving adequate ignition by coal or wood to the three retorts. The retorts were built up in an excellent manner by an English mason perfectly acquainted with the best modes of erecting coal-gas retorts, who was sent over on purpose.

In the section, *fig.* 1444, *a* is the body of the retort; its mouth at the right-hand end is shut, as usual, by a luted iron lid, secured with a cross-bar and screw-bolts; its other end is prolonged by a sloping pipe of cast iron, 4 inches in diameter, furnished with a nozzle-hole at L, closed with a screw-plug. Through this hole a wire rammer may be introduced, to ascertain that the tube is pervious and to cleanse it from the mercurial soot, when thought necessary. *c* is a cross section of the main condenser, shown in a longitudinal section at C C, *fig.* 1445. This pipe is 18 inches in diameter, and about 20 feet long. At *a a*, &c., the back ends of the retort are seen, with the slanting tubes *b b*, &c., descending through orifices in the upper surface of the condenser-pipe, and dipping their ends just below the water-line *h i*. *g* is the cap of a water-valve, which removes all risk from sudden expansion or condensation. The condenser is placed within a rectangular trough, made either of wood or stone, through which a sufficient stream of water passes to keep it perfectly cool, and repress every trace of mercurial vapour, and it is laid with a slight inclination from *i* to *h*, so that the condensed quicksilver may spontaneously flow along its bottom, and pass through the vertical tube, D, into the locked-up iron chest, or magazine, *e*. This tube, D, is from the beginning closed at bottom, by immersion in a shallow iron cup, always filled with mercury. *k* is a graduated gauge-rod, to indicate the progressive accumulation of quicksilver in the chest, without being under the necessity of unlocking it.

1445



The air-tight apparatus was erected some years ago, and was found to act perfectly well. The whole cost of the nine large retorts, with their condensing-apparatus, iron-magazine, &c., was very little more than *two hundred pounds*! As the retorts are kept in a state of nearly uniform ignition, like those of the gas-works, neither they nor the furnaces are liable to be injured in their joints by the alternate contractions and expansions, which they would inevitably suffer if allowed to cool; and being always ready heated to the proper pitch for decomposing the mercurial ores, they are capable of working off a charge, under skilful management, in the course of 3 hours. Thus, in 24 hours, with a relay of labourers, 8 charges of at least 5 cwts. of ore each might be smelted = 2 tons with 3 retorts, and 6 tons with 9 retorts; with a daily product from the rich ores of Almaden, or even Idria, of from 12 cwts. to 20 cwts.

The following detailed account of the apparatus for smelting in California is given by Mr. Ruschenberger:—A kind of reverberatory-furnace 3 feet by 5, is arranged at the extremity of a series of chambers of nearly, if not exactly of the same dimensions: namely 7 feet long, 4 feet wide, and 5 feet high. There are 8 or 10 of these chambers in each series; they are built of brick, plastered inside, and secured by iron rods, armed at the end with screws and nuts as a protection against the expansion by heat. The tops are of boiler-iron, luted with ashes and salt. The first chamber is for a wood fire. The second is the ore-chamber, which is separated from the first by a network partition of brick. The flame of the fire passes through the square holes of this partition, and plays upon the ore in the ore-chambers, which, when fully charged, contains 10,000 lbs. of cinnabar; next to the ore-chamber is the first condensing-chamber, which communicates with it by a square hole at the right upper corner; and the communication of this first with the second condensing-chamber is by a square hole at the left lower corner. An opening at the right upper corner of the partition, between the second and third condensing-chambers, communicates with the latter. The openings between the chambers are at the top, and to the right, and at the bottom, and to the left alternately; so that the vapours from the ore-chamber are forced to describe a spiral in their passage through the 8 condensers. The vapour and smoke pass from the last condensing-chamber through a square wooden box, 8 or 10 feet long, in which there is a continuous shower of cold water, and finally escape into the open air by tall wooden flues. The floor, or bottom, of each condensing-chamber is above 2 feet above the ground, and is arranged with gutters for collecting the condensed mercury, and conveying it out into an open conduit along which it flows into an iron receptacle, from which it is poured into the iron flasks through a brush, to cleanse it of the scum of oxide formed on the surface on standing. 70 lbs. weight are poured into each flask. There are 14 of these furnaces and ranges of condensers, with passages of 8 or 10 feet in width between them. A shed is constructed above the whole at a sufficient elevation to permit free circulation of the air.

According to Dumas, the following mines yield annually as follow:—Almaden in Spain, from 2,700,000 to 3,456,000 lbs. avoirdupois; Idria, 648,000 to 1,080,000 lbs.; Hungary and Transylvania, 75,600 to 97,200 lbs.; Deux Points, 43,000 to 54,000 lbs.; Palatinate, 19,440 to 21,600 lbs.; Huancavelica, 324,000 lbs.

The *Imports* of mercury for the years 1868–72 have been as follow:—

	1868		1869		1870	
	Lbs.	Computed real value	Lbs.	Computed real value	Lbs.	Computed real value
		£		£		£
From France	...	...	45,386	4,019	...	...
,, Spain	3,146,720	278,621	2,380,326	210,757	2,553,861	257,370
,, Italy (Tuscany)	...	...	29,084	2,575	70,740	8,709
,, Austrian Territories	...	...	...	...	...	...
,, North Atlantic Ports	90,773	8,037	...	...	...	...
,, Ports on the Pacific	187,951	16,641	53,760	4,760	...	...
,, Other parts	6,285	556	18,196	1,611	20,124	2,031
,, Portugal	...	...	...	...	121,055	16,393
Total	3,431,729	303,855	2,526,752	223,722	2,765,780	284,503

	1871		1872	
	Lbs.	Computed real value	Lbs.	Computed real value
		£		£
From Spain	41,325	4,735	51,050	369,118
,, Italy (Tuscany)	91,439	9,669	93,201	11,525
,, Austrian Territories	135,976	20,000	122,536	18,137
,, Other parts	12,750	1,201	3,525	575
,, Portugal	2,721,407	379,360	2,416,782	369,112
Total	3,431,729	414,965	2,734,094	407,229

The *Exports* were as follow from the Californian mines:—

	1867	1868	1869	1870
	flasks	flasks	flasks	flasks
To New York	2,900	4,500	1,500	1,000
,, Great Britain	1,500	3,500	...	...
,, China	10,011	17,785	11,600	4,050
,, Mexico	10,042	14,120	8,060	7,088
,, South America	3,800	2,500	2,900	1,300
,, Australia	300	1,580	300	300
,, British Columbia	20	20	4	9
,, Other countries	280	501	51	41
Total	28,853	44,506	24,415	13,788

Mercury is a substance of paramount value to science. Its great density, and its regular rate of expansion and contraction by increase and diminution of temperature, give it the preference over all liquids for filling barometric and thermometric tubes. In chemistry it furnishes the only means of collecting and manipulating, in the pneumatic trough, such gaseous bodies as are condensible over water. To its aid, in this respect, the modern advancement of chemical discovery is pre-eminently due.

This metal, alloyed with tin-foil, forms the reflecting surface of looking-glasses, and, by its ready solution of gold or silver, and subsequent dissipation by a moderate heat, it becomes the great instrument of the art of gilding and silvering copper and brass. The same property makes it so available in extracting these precious metals from their ores. This amalgam is used for electric machines. The anatomist applies it elegantly, to distend and display the minuter vessels of the lymphatic system, and secretory systems, by injecting it with a syringe through all their convolutions. It is the basis of many very powerful medicines.

The nitrate of mercury is employed for the *secretage* of rabbit- and hare-skins, that is, for communicating to fur of these and other quadrupeds the faculty of felting, which they do not naturally possess. With this view, the solution of that salt is applied to them lightly in one direction with a sponge.

The only mercurial compounds which are extensively used in the arts are factitious cinnabar or VERMILION, and CORROSIVE SUBLIMATE, which see.

MERCURY, CHLORIDE OF; PROTOCHLORIDE (*Deutochlorure de mercure*, Fr.; *Aetzendes quecksilber sublimat*, Ger.) is made by subliming a mixture of equal parts of persulphate of mercury and sea-salt in a stoneware cucurbit. The sublimate rises in vapour, and incrusts the globular glass capital with a white mass of small prismatic needles. It is a very deadly poison; raw white-of-egg, swallowed in profusion, is the best antidote. See CORROSIVE SUBLIMATE.

MERCURY, FULMINATING. For this compound of mercury with fulminic acid, see FULMINATING MERCURY.

MERCURY, PERIODIDE OF, is a bright but fugitive red pigment. It is easily prepared by dropping a solution of iodide of potassium into a solution of corrosive sublimate, as long as any precipitation takes place, decanting off the supernatant muriate of potash, washing and drying the precipitate.

MERCURY, SUBCHLORIDE OF; *Calomel.* (*Protochlorure de mercure*, F ; *Versüsstes quecksilber*, Ger.) See CALOMEL.

MERINO. For the following we are indebted to the 'History of the Woollen Trade of Bradford,' by John James:—

George III., ever desirous of the welfare of his people, though oftimes mistaken in the means for accomplishing his wishes, amongst other improvements projected by him in agriculture and husbandry, imported in 1786 a few merino sheep from Spain, for the purpose of improving the wool of England. Unquestionably this variety of sheep sprung from the English flock which Edward III. permitted to be exported to Spain, where, by assiduous care and crossing, the fleece had become the finest in its staple of any in the world. His Majesty made from time to time considerable accession to his original flock, which throve well, and increased very fast, so that in a few years, by distribution and sale, they had come into the hands of the most eminent sheep-breeding gentlemen in the kingdom. Among these the late Lord Western stood the most distinguished for his breeding and culture of merino sheep. His flock had its origin in a gift from His Majesty of 40 ewes, selected from 500 merinos sent by the Cortes of Spain to the king for distribution among his subjects. His lordship's chief care in his improvement of the fleece was to adapt it for the finest articles of worsted, and he certainly succeeded well in his object. Many other sheep-breeders in the kingdom also devoted much attention, with great success, to the breeding of merino sheep, so that at this period (1826) large quantities of such wool were produced in the country.

Contemporaneous with these efforts made in England, the propagation of the merino sheep, which had been obtained from Spain, was carried on to a great extent in Saxony, where the ruling monarch, like our own, took much interest in the enterprise. The government of Saxony was amply rewarded for the pains which had been taken to spread the breeds so as to become a portion of the public wealth. Hence from this source arose the large supply which enabled Saxony to send to this country large quantities of wool, chiefly for the making of fine woollen cloth, as it, on the whole, ranged in staple shorter than English or Spanish merino. Nor were the French idle in availing themselves of the excellent properties of the Spanish sheep by transplanting them to their soil, and manufacturing from the wool fine stuffs to which they gave the name of merinoes.

From the merino wool produced in France and Germany were manufactured fine descriptions of stuffs named after the sheep. A Bradford spinner in 1826, being desirous of extending his export trade in Germany, instituted inquiries respecting the stuffs made there, and received in answer the following information:—No worsted yarn of any amount was made on the Continent, except by hand. As the laws prohibiting the exportation of English machinery still remained in force, the continental nations could not obtain our improved frames, and either their handicraftsmen were unable to construct them with sufficient skill, or their capitalists were disinclined to embark in the enterprise. Much yarn was spun by hand in the neighbourhood of Hamburgh. Then, as to the weaving of stuffs, a few merinoes were made at Leipzig, and some of them from English yarn spun to No. 46. At Waldenberg, Eisenach, and Langensalza, Berlin, Altona, and Erfurt, merinoes were made. For some of these English yarn was used, but the German manufacturers preferred, most likely for its durability, their own yarn. Whilst the French and Germans were weaving merino pieces, a fabric bearing the same name, but widely differing in structure, arose in the English market, and imparted a most beneficial impulse to the stuff trade of the West Riding.

A brief narration of the origin of English merinoes will at this point, find an appropriate place. The wearing of worsted stuffs, after many changes of fashion, had again become very common amongst people of every degree in England. But it was perceived as the taste for fabrics of fine texture increased, that plainbacks and other worsted articles of that kind were not sufficiently delicate in structure for the higher classes. This idea having been mentioned by one of the partners in the house of Messrs. Todd, Morrison, and Co., warehousemen, London, to Messrs. Mann of Bradford, merchants, the latter began to reflect on the best method of supplying the void. It occurred to them that a plainback made with the finest yarn, and spun from merino and other fine wools, would answer the object.

Accordingly they employed Messrs. Garnett of Bradford to spin yarn and manufacture such a stuff, who accomplished the task to the full satisfaction of their employers. Some beautiful pieces were the result; three-quarters wide, made from 40's to 52's weft, and 32's to 34's warp; in every respect they resembled Cashmere, except in being finer. From the period of their introduction, these stuffs pleased the public taste, and were rapidly sold at high prices. They were originally sold at from 75*s.* to 80*s.* the piece; but when the article became known, many manufacturers entered into competition, and making lower sorts, reduced the prices from 40*s.* to 50*s.* the piece according to qualities.

About a year after the full introduction of the three-quarters merino into the market, it was found that, owing to the narrowness of the piece, it did not cut up conveniently or economically for dresses; and the six-quarter variety of merino was brought into the market, where it for many years had a large demand, bringing as much in some instances as 120*s.* a piece.

MESSENGER. A hawser, or small cable, about sixty fathoms long, wound round the capstan, and having its two ends lashed together. See CABLE.

METACINNABAR. An amorphous dark-coloured sulphide of mercury found in California.

METAL. This term is sometimes applied by smelters to a regulus, or fixed sulphide, such as the 'coarse metal' and 'blister metal' of the copper-smelter. The molten glass is spoken of in glass-works as 'metal.'

METAL LEAF. A name commonly applied to the Dutch leaf to distinguish it from gold-leaf. There was of metal leaf not gold *imported* in 1868–72:—

Metal leaf, not gold	1868		1869		1870		1872	
	Packets of 250 leaves	Computed real value	Packets of 250 leaves	Computed real value	Packets of 250 leaves	Computed real value	Packets of 250 leaves	Computed real value
		£		£		£		£
From Holland . .	451,849	33,890	317,194	23,789	276,010	20,701	115,522	5,650
„ Belgium . .	238,070	17,855	337,530	25,315	233,040	17,479	..	..
„ Germany . .	..	..	..	..	..	..	61,468	2,916
„ Other parts . .	22,476	1,686	1,804	137	56,826	4,263	29,539	1,974
Total . .	712,395	53,431	656,528	49,241	565,876	42,443	206,529	10,537

METALLOGRAPHY. A process invented by M. Abate, and published by him in 1851. It consists of printing from engraved wood-blocks upon metallic surfaces, so as to produce imitations of figures and ornaments inlaid in wood. This effect he obtained by using, as a printing menstruum to wet the block with, solutions of such metallic or earthy salts as are decomposed when brought into contact with certain metals, and produce, through an electro-chemical action, an adhesive precipitate of a coloured metallic oxide, or any other chemical change upon the metal.

METALLOÏDS. Davy proposed this name for sodium and potassium, and other substances of which the metallic character was not well defined. Berzelius used the term to distinguish the *non-metallic* elementary substances from the metals. Dr. Apjohn published a 'Manual of the Metalloïds,' in which he adopted this meaning. The word metalloïd signifying *like a metal*, its use in this sense is unfortunate.

METALLURGY. (*Hüttenkunde*, Ger.) The art of extracting metals from their ores. Under the heads of the different metals respectively, the metallurgical processes to which they are subjected are given. See ANTIMONY, COPPER, GOLD, IRON, &c. A full description of the processes of preparing the minerals for the operations of the metallurgist will be found under the head of DRESSING OF ORES.

When it is intended to wash certain ores, an operation founded on the difference of their specific gravities, it may happen that by slightly changing the chemical state of the substances that compose the ore, the earthy parts may become more easily separable, as also the other foreign matters. With this view, the ores of tin are subjected to a roasting, which, by separating the arsenic and oxidising the copper which are intermixed, furnishes the means of obtaining, by the subsequent washing, an oxide of tin much purer than could be otherwise procured. In general, however, these are rare cases; so that the washing almost always immediately succeeds the picking and stamping; and the roasting comes next, when it needs to be employed. See ROASTING ORES.

METALS (*Métaux*, Fr.; *Metalle*, Ger.) are by far the most numerous class of undecomposed bodies in chemical arrangements. They amount to 51; of which 7 form, with oxygen, bodies possessed of alkaline properties: these are, 1. potassium; 2. sodium; 3. lithium (bases of the alkalis); 4. barium; 5. strontium; 6. calcium; 7. magnesium (bases of the alkaline earths, for even magnesia, the last and feeblest base, tinges turmeric brown, and red cabbage green). The next seven metals form with oxygen the earths proper: they are, 8. yttrium; 9. glucinum; 10. aluminium; 11. zirconium; 12. thorium; 13. erbium; 14. terbium. The remaining 37 may be enumerated in alphabetical order, as they hardly admit of being grouped into subdivisions with any advantage. They are as follow: 15. antimony; 16. arsenic; 17. bismuth; 18. cadmium; 19. cerium; 20. chromium; 21. cobalt; 22. copper; 23. didymium; 24. gold; 25. iridium; 26. iron; 27. lead; 28. lanthanum; 29. manganese; 30. mercury; 31. molybdenum; 32. nickel; 33. niobium; 34. osmium; 35. palladium; 36. platinum; 37. rhodium; 38. ruthenium; 39. silver; 40. tantalum; 41. tellurium; 42. tin; 43. titanium; 44. tungsten; 45. vanadium; 46. uranium; 47. zinc; and lately by spectrum analysis the following have been discovered, 48. cœsium; 49. indium; 50. rubidium; and 51. thallium.

1. They are all, more or less, remarkable for a peculiar lustre, called the *metallic lustre*. This property of strongly reflecting light is connected with a certain state of aggregation of their particles, but is possessed, superficially at least, by mica, animal charcoal, selenium, polished indigo, and bodies which are not at all metallic.

2. The metals are excellent conductors of heat, and most of them also of electricity, though probably not all. According to Despretz, they possess the power of conducting heat proportionately to the following numbers:—Gold, 1,000; platinum, 981; silver, 973; copper, 898; iron, 374; zinc, 363; tin, 304; lead, 179·6.

Becquerel gives the following table of metals, as to electrical conduction:—

Copper, 100; gold, 93·6; silver, 73·6; zinc, 28·5; platinum, 16·4; iron, 15·8; tin, 15·5; lead, 8·3; mercury, 3·5; potassium, 1·33.

The metals which hardly, if at all, conduct electricity, are zirconium, aluminium, tantalum, in powder, and tellurium.

3. Metals are probably opaque; yet gold-leaf, as observed by Newton, seems to transmit the green rays, for objects placed behind it in the sunbeam appear green. This phenomenon has, however, been ascribed to the rays of light passing through an infinite number of minute fissures in the thinly-hammered gold.

4. All metals are capable of combining with oxygen, but with affinities and in quantities extremely different. Potassium and sodium have the strongest affinity for it; gold and the platinum-group of metals the feeblest. Many metals become acids by a sufficient dose of oxygen, while, with a smaller dose, they constitute salifiable bases.

5. Metals combine with each other, forming a class of bodies called alloys, except when one of them is mercury, in which case the compound is styled an amalgam.

6. They combine with hydrogen into *hydrurets* or *hydrides*; with carbon, into *carburets* or *carbides*; with sulphur, into *sulphurets* or *sulphides*; with phosphorus, into *phosphurets* or *phosphides*; with selenium, into *seleniurets* or *selenides*; with boron, into *borides*; with chlorine, into *chlorides*; with iodine, into *iodides*; with cyanogen, into *cyanides*; with silicon, into *silicides*; and with fluorine, into *fluorides*.

7. Metallic salts are definite compounds—mostly crystalline—of the metallic oxides with the acids.

METALS, NATIVE. The metals which are found in the condition of obvious metallic existence are but few. *Gold* is almost always found native, generally combined with a small percentage of silver, and sometimes with other rarer metals. *Silver* is frequently discovered in an almost pure metallic state. *Platinum* is another metal, which, like gold, is generally found in the metallic state, but this metal is almost always combined with palladium, osmium, and other metals of that type. *Copper* is very often found in the native state, and in a condition of great purity. The occurrence of large masses of copper—copper rocks, indeed—is one of the most striking features of the Lake Superior copper deposits. *Lead* is said to have been found native at Grassington, in Yorkshire. Recently it is reported to have been discovered in Victoria, Australia, and again in California. *Bismuth* is often found native; and *Iron*, the meteoric variety, is occasionally met with in this condition.

METALS, NOBLE. This term was applied to gold and silver in ages when the principles of chemical science were unknown. The name was intended to convey the fact that these metals were slow to combine with the 'baser ones,' such as iron. The term is not now employed scientifically.

METEORITES. (*Aérolithe*, Fr.) The name of mineral bodies which have been known to fall from the region beyond the earth's atmosphere to the surface of the earth. There are, however, a certain number of bodies found on the surface in various parts of the world, which are thought to be of meteoric origin, and are hence called *Meteorites*, which correspond in chemical composition and structure with those which have been seen to fall. They are usually divided into *Meteoric Iron* and *Meteoric Stones*. The meteoritic irons have been termed *Siderites*, whilst the term *Aerolites* has been retained for the stony meteorites. The following may be regarded as the average composition of meteoric iron: Iron, 85·54; nickel, 8·55; cobalt, 1·50; copper, 0·20; magnesia, 2·04; chromic oxide, 0·21; silica, 3·0; phosphorus, 0·12; with traces of carbon, sulphur, tin, and manganese. For numerous analyses, see Watts's 'Dictionary of Chemistry.' See AEROLITES.

METHYLAMINE. C^2H^5N (**CH^5N**). The most volatile of the organic bases. It is formed by similar reactions to ethylamine; it is regarded as ammonia in which an equivalent of hydrogen is replaced by methyle; it is gaseous at ordinary temperatures; it is the most soluble in water of all known gases, one volume of water at 54° dissolving 1,150 volumes.

METHYLATED SPIRIT. When ordinary alcohol is mixed with 10 per cent. of 'wood alcohol' (*Methyle*), it is, according to an excise regulation, sold duty free under this name. Methylated spirit is extensively used in the manufacture of varnishes, lacquers, &c. See Watts's 'Dictionary of Chemistry.'

METHYLENE, a peculiar liquid compound of carbon and hydrogen, extracted from pyroxilic spirit, which is reckoned to be a bi-hydrate of *methylène*.

METRIC SYSTEM. See WEIGHTS AND MEASURES.

MICA is a finely-foliated mineral, of a pearly metallic lustre. It is harder than gypsum, but not so hard as calc-spar; flexible and elastic; spec. grav. 2·65. It is an ingredient of granite and gneiss. The large sheets of mica exposed for sale in London are mostly brought from Siberia. They are used, instead of glass, to enclose the fire, without concealing the flame, in certain stoves.

The mica of Fahlun, analysed by Rose, afforded silica, 46·22; alumina, 34·52;

peroxide of iron, 6·04; potash, 8·22; magnesia, with oxide of manganese, 2·11; fluoric acid, 1·09; water, 0·98. From an American authority we quote as follows:—

'The increased demand for gas-stoves has naturally introduced to a wider notice the really valuable and useful mineral known under the name of mica. Every schoolboy can pick out the mica in a piece of granite, but it is not so well known that the 'glass' forming the front of many kinds of gas-stoves is also mica. The minerals which form the group of micas divide readily into two divisions; those which are silicates of alumina and an alkali, and those which are silicates of magnesia. They are all notable for their lustre, and for their distinct cleavage, which permits of their being separated into thin sheets. In granite, the plates are rarely seen of a useful size, although in the coarser descriptions of that rock plates are occasionally found a foot and more in width; but, in limestone formations, it is often found in masses of considerable size, plates having been met with in Siberia several feet in diameter. The micas chiefly met with in commerce are Muscovite and Lepidolite (or lithia mica) of the first division, and Phlogopite (rhombic mica) and Biotite of the latter division, or magnesian micas. Of these, the most extensively used in the arts are Muscovite and Phlogopite. The former is mainly a silicate of alumina and potash, with traces of iron, fluorine, chromium, &c., which impart colour to the otherwise grey or silver-white plates of mica. The crystals of Muscovite are usually six-sided; the colour varying from black through grey to green, chromium being invariably present in the crystal of the last-mentioned tint. This variety of mica is proof against acids, is very refractory, the thin edge only fusing before an ordinary blowpipe, while the laminæ are very tough and flexible. Phlogopite, or rhombic mica, as it is sometimes called, is mostly found in limestone, and is composed mainly of silica, alumina, and magnesia, with traces of iron, potash or soda, and fluorine. Its colour varies from brown, through brownish yellow, to grey. If it is previously reduced to fine powder, it is attacked by hot sulphuric acid, but, like Muscovite, although it whitens in the blowpipe-flame and fuses on the thin edges, it is virtually refractory to anything short of an intense heat. These extraordinary properties, combined with toughness and elasticity, and the peculiar facility with which it splits into thin sheets, some of which approach closely to transparency, led naturally to the use of mica for windows, and especially to its employment in lanterns. For many years it has been used in Russia for windows, and in some parts is still to be found, though it is of course rapidly giving way to the more transparent glass. So common, however, was its employment for this purpose at one time in Russia, that it was frequently called 'Muscovy glass.' It is found in Siberia, Sweden, and Moravia, which also supply the Lepidolite, or lithia mica. In America it is found in various parts, as North Carolina, New Jersey, and Canada. In some coarse granite rocks of the first-named State the mica is found in considerable abundance, and there are unmistakable evidences that it was worked many years ago. The commercial value of mica varies through a wide scale: the large, sound, and clear sheets being naturally the highest priced, fetching as much as 40*s.* a pound. In the United States, where large quantities are used for what is called 'stove glass,' that is, for the fronts of gas and other stoves, the utilisation of mica has been carried further than in this country. The small and waste-stuff is there made into a coarse powder and sprinkled over tar in roof-making; finely ground, it is used as a lubricant, and is sometimes used in packing deed-boxes and safes to render them fireproof. The finer sheets are used for such purposes as the dials of compasses, for the letters of fancy signs, and the very finest and thinnest pieces are sometimes employed in lieu of enamel for covering photographs; but one of the principal uses to which the better qualities are put is the construction of shades for lamps, the nature of the material rendering its decoration a comparatively easy process: chromo-lithography being extensively employed in this manufacture. The preparation of the mica is very easy. When first obtained it is in plates and crystals of various sizes, from a quarter of an inch to even occasionally a foot in thickness, and from six inches to a foot and upwards in diameter.

'The facility with which they can be bent into various shapes, and the power they possess of resisting heat, together with their transparency and naturally beautiful appearance, make these thin sheets of mica of peculiar value in many situations. They have been used as reflectors for some years, and a patent has recently been obtained for an improved process of silvering plates of mica, the inventor being a resident of Philadelphia. The flexible nature of the material to be silvered will probably insure its introduction into the arts and industries to a greater or lesser extent, and it is perhaps not impossible that it may be employed in the manufacture of telescopes, although it must be confessed that its utilisation for that purpose is rather improbable. In the process recently patented, sheets of mica, as free from metallic deposit as can be obtained, are thoroughly washed in nitric acid, and then rinsed in water. They are then placed upright in suitable vats or baths, being arranged in pairs, back to back, so as to expose only one side to the coating solution. This latter is tolerably well known, and is made by dissolving 1 oz. of nitrate of silver in a quart of distilled water, and in a separate vessel 1 oz. of glucose in a quart of distilled water. When the silver has dissolved, a small quantity of liquor ammoniæ is added, and the solution becomes cloudy, the cloudiness disappearing on the addition of a little more ammonia. When this stage has been arrived at, the two solutions are mixed together and poured into the bath containing the mica plates, the bath being placed in a warm room, to facilitate the deposition of the silver. When the mica plates are sufficiently coated they are withdrawn from the bath, thoroughly rinsed in water and stood away to dry, after which they may, if deemed necessary, be coated with spirit-varnish.

The mica plates thus prepared may be mounted on frames of tin, sheet iron, paper, or plastic composition. Many other applications of these mica reflectors will suggest themselves to our readers, though their principal use is undoubtedly for illuminating purposes.'

MICACEOUS IRON. One of the varieties of hæmatite; so called from its micaceous structure. See IRON.

MICA-SLATE or **SCHIST.** (*Schisma*, Ger. a splitting.) A foliated rock composed of mica and quartz. The first name is not correctly applied.

MICROCOSMIC SALT. A term given to a salt extracted from human urine. It is a phosphate of soda and ammonia; and is now prepared by mixing equivalent proportions of phosphate of soda and phosphate of ammonia, each in solution, evaporating and crystallising the mixture. A small excess of ammonia aids the crystallisation.

MILDEW, MANCHESTER. From imperfect manufacture—or from corrupt practices—it appears that a peculiar mildew has often developed itself in cotton goods sent to India, to which this name has been given. The Manchester Chamber of Commerce has just (1874) received a letter from the Shanghai General Chamber of Commerce respecting 'mildewed shirtings,' which will probably open the eyes of those concerned in the matter to the fact that, after all, honesty is perhaps the best policy, and that there is a point beyond which swindling cannot be carried without its evil effect recoiling on its authors. The Chairman of the Shanghai Chamber, writing on December 17, 1872, calls attention to the widespread deterioration by mildew of cotton piece goods imported to China from Manchester. The losses from this cause have for some time been very large; but towards the end of 1871 parcel after parcel of grey shirtings, principally if not wholly consisting of second and lower qualities, were rejected by the Chinese buyers as 'spotted,' and during the past year the evil has become so general that in September last it was estimated that 75 per cent. of the entire stock of grey shirtings and T cloths in Shanghai were unmerchantable as sound goods. The trade was, in fact, completely disorganised. The cause of the deterioration is, there is strong reason to believe, owing to the use of 'size' in undue quantity and of a nature deleterious to the fabric employed to work up inferior cotton and to increase the weight of the cloth. The results of the extensive importations of unsound goods into China are that large quantities of cloth are forced off at reduced and irregular prices, by which means the tone of the market is lowered and the value of even sound goods is depreciated. Bales are no longer, as was once the case, accepted unopened on the faith of the sample, but the wrappers have to be cut into in order that the condition of every package may be ascertained. The inconvenience, delay, and loss arising from this practice are obvious. The trouble and waste of time entailed by the necessity of minute inspection, the frequent resales of rejected parcels, and the uncertainty as to the completion of any sale, until full examination of the contents of the packages has been made, all represent a positive burden on the trade. The destruction of the packages is, moreover, a loss to the native merchant, who can never again pack his goods so securely for inland transport. More important, perhaps, than all, is the fact that the confidence of native dealers and merchants in foreign goods is shaken; for they are no longer sure of carrying their purchases to the end of a long journey in a merchantable condition. Such general want of confidence in the soundness of foreign cotton goods must tend, it is urged, to render them unpopular among the Chinese; and, considering that foreign imports, though cheaper, have great difficulty even under favourable circumstances in competing with the more durable native manufactures, the trade is not in a position to bear any additional burden. Although, therefore, the first losses from mildew fall upon the importing merchant, while the manufacturers appear to escape altogether, yet such an unequal distribution of the responsibility cannot continue, if for no better reason than that the magnitude of the losses will soon put it beyond the power of the merchants to bear them, were they ever so willing. The result will, therefore, ultimately affect the Manchester manufacturers as seriously as the China merchants, and the latter urge the Manchester Chamber of Commerce to join with them in a strict investigation into the circumstances with a view of putting an end to 'a crying evil affecting not only the interests of the most important branch of British industry, but also the honour and reputation of British commerce.'

MILFOIL. (*Millefolium*, Lat. a thousand leaves.) The herb yarrow, belonging to the genus *Achillea*, one of the *Compositæ*.

MILK. A well-known nutritious fluid, which, as it has no especial use in the arts, need not be described. See BUTTER.

MILK, CONDENSED. The following information on the processes for condensing milk successfully is obtained from two journals known as the 'Farmer' and 'Moore's Rural':—

In the first place, arrangements must be made for obtaining good, clean, healthy milk, and this imposes a sort of education upon those producing milk, of the utmost importance to the successful prosecution of the condensing business. Dirty milk—milk foul with the drippings of the stable—cannot be condensed into a clean-flavoured product. The success of the condensing factory depends almost entirely upon the ability to put a fine-flavoured, perfect article into the market. The milk must be uniformly good. An inferior condensed milk is more readily detected than an inferior article of cheese or butter. At least, imperfections in these may perhaps be tolerated, and the goods may find a place in the market; but a factory continuing to send out imperfect or badly-flavoured milk, must soon cease to be remunerative, and must inevitably close its doors.

To obtain any success in this business, there is absolute necessity for clean, healthy milk in the first instance; and this matter should be well understood and well considered before any manufacture can be attempted. The great success attained by the late Gail Borden, the inventor of the process for condensing *in vacuo*, was in a great measure due to the system he inaugurated among his patrons for supplying milk free from all taint and unobjectionable in quality. He instituted a set of rules for the guidance of dairymen furnishing milk to his factories, which he rigidly enforced, and men were regularly employed to visit the farms from time to time, to see in what manner the cows were managed as to pasturage, water, driving to the yard, milking, cooling and care of milk; and as he bought, or accepted only such milk as would pass the closest scrutiny of an expert, he was able, after a time, to enforce an observance of his printed regulations, which he put into the hands of his dairymen. He adopted also, the practice of cleaning and steaming his patrons' delivery milk-cans at the factory, because he feared—and with good reason too—that this work might not be properly done at the farm.

The Borden process for condensing milk, the only process, we believe, which has stood the test of time and proved to be a success, may be briefly described as follows:—'After the milk is received at the factory it passes through a strainer to the receiving vat; from this it is conducted off through another strainer into the heating cans, each holding about 20 gallons; these cans are set in hot water, and the milk is held in them till it reaches a temperature of 150° to 175° Fahr.; it then goes through another strainer into a large vat, at the bottom of which is a coil of copper-pipe, through which steam is conducted, and here the milk is heated up to boiling point. Then the best quality of white granulated sugar is added in the proportion of 1½ lb. of sugar to 1 gallon of milk, when it is drawn into the vacuum-pan. The milk remains in the vacuum-pan subjected to steam for about three hours, during which time about 75 per cent. of its bulk in water is removed, when it is drawn off into cans holding about 40 quarts each.

These cans are only partially filled, and then set in a large vat containing cold water, the water being of a height equal to that of the milk in the cans. Here it is stirred until the temperature of the condensed fluid is reduced to a little below 80° Fahr. It is then turned into large draining cans with faucets, in order to facilitate the filling of the smaller cans. The draining cans stand in a room which is set apart for the purpose, and around the outside of which runs a table or work-bench. Here the milk is drawn from the faucets into small tin cans, holding 1 lb. each, when they go to the table, and are immediately soldered, to exclude the air. The cans next have the proper labels pasted upon them, and are then ready for market.

Somewhat recently Mr. Borden introduced a machine for filling the cans, which does the work with accuracy and rapidity. The work of filling the cans, soldering the tops and labelling, is usually performed by females. A number of small soldering furnaces are placed along the tables, where the girls, each with a set of soldering irons, seal the cans as fast as they are brought forward by the fillers.

For a small factory, say for the milk of from 200 to 300 cows, the estimated cost will be about 13,000 dols., as follows:—Erection of the building, 16 ft. by 50 ft., ready for machinery, &c., 2,500 dols.; vacuum-pan and condenser, from 3 ft. to 4 ft. in diameter, 1,800 dols.; 1 duplex 14-inch pump and engine, 1,500 dols.; 1 boiler, 60-horse power and fitting-up, 3,000 dols.; 1 pump for boiler, 100 dols.; outside water-pipes, 500 dols.; 1 cooling tank for receiving and storage, 500 dols.; 1 heating tank and pipes for milk, 300 dols.; hot water tank and steam-pipes for washing cans and 2 rinsing sinks, 600 dols.; 1 steamer-bath for scalding cans and pipes, 150 dols.

It will be seen from the above, that a well-furnished factory, with all the needful appliances, is somewhat expensive; but the profits from the business are also considerable. The cost of condensing will probably be no more than one-half per cent. per quart. It takes about 3 pints of milk to make 1 lb. of the sugared condensed milk, which sells in the market for 25 cents and upward. It is not easy to give the exact cost of condensing, since that will depend upon the amount of milk worked and the economy with which the factory is managed; but we should say that 1*d.* per quart ought to cover all the expenses for condensing. The cans, and the labour of filling and soldering, are an additional expense, which our readers can figure approximately, so that some idea of the profits may be obtained.

There are two kinds of condensed milk in the market:—the sugared, as above described, and which will keep for long periods, and the plain condensed milk, which contains no sugar, and is sold for immediate use. This last will only keep sound for a few days. It is made in the same way as the other, except that no sugar is used in its manufacture. A less price is obtained for it in the market than for sugared milk, it being sold by the quart from large carrying cans, and regularly furnished to consumers from time to time.

One great difficulty in the way of establishing new factories, is in obtaining skilled workmen to conduct the business of condensing. There are comparatively few persons who have had experience in the work of a factory, and these are, for the most part, retained by these factories now in successful work. As these factories have built up a good trade and have a 'good thing,' they do not care to open their doors for instruction or to educate any person in the business who would engage in a new factory. In cheese-making or in butter-making there are always plenty of skilled hands to be had, but the case is quite different in the condensing business, and this fact has deterred many from entering upon the work.

MILL, THE. A name given to the cylinder used by the calico-printers, in which the impression is obtained by a process like that of a milling tool, from a cylinder engraved by hand, called *the Die.* See CALICO-PRINTING.

MILL-STONE, or *Buhr-Stone.* This interesting form of silica, which occurs in great masses, has a texture essentially cellular, the cells being irregular in number, shape, and size, and are often crossed by thin plates, or coarse fibres of silex. The buhr-stone has a straight fracture, but it is not so brittle as flint, though its hardness is nearly the same. It is feebly translucent; its colours are pale and dead, of a whitish, greyish, or yellowish cast, sometimes with a tinge of blue.

The Buhr-stones usually occur in beds, which are sometimes continuous, and at others interrupted. These beds are placed amid deposits of sand, or argillaceous and ferruginous marls, which penetrate between them, filling their fissures and honeycomb cavities. Buhr-stones constitute a very rare geological formation, being found in abundance only in the mineral basin of Paris, and a few adjoining districts. Its geological position is well ascertained: it forms a part of the lacustrine, or fresh-water formation, which, in the locality alluded to, lies above the upper eocene gypsum, and the stratum of sand and marine sandstone which cover it. Buhr-stone constitutes, therefore, in the locality in which it is found, the uppermost solid stratum of the crust of the globe; for above it there is nothing but alluvial soil, or diluvial gravel, sand, and loam.

Buhr-stones sometimes contain no organic forms; at others they seem as if stuffed full of fresh-water shells, or land-shells and vegetables of inland growth. There is no exception known to this arrangement; but the shells have assumed a siliceous nature, and their cavities are often filled with crystals of quartz. The best buhr-stones for grinding corn have about an equal proportion of solid matter and of vacant space. The finest quarry of them is upon the high ground, near *La Ferté sous Jouarre.* The stones are quarried in the open air, and are cut out in cylinders from one to two yards in diameter, by a series of iron and wooden wedges, gradually but equally inserted. The pieces of buhr-stones are afterwards cut into parallelopideds, called *panes,* which are bound with iron hoops into large millstones. These pieces are exported chiefly to England and America. Good millstones of a bluish-white colour, with a regular proportion of cells, when 6½ feet in diameter, fetch 1,200 francs apiece or 48*l.* sterling. A coarse conglomerate sandstone or breccia is, in some cases, used as a substitnte for buhr-stones; but it is a poor one.

In addition to the French buhr-stone, other materials are employed as millstones. Thus the lava of Niedermendig, near Andernach, on the Rhine, has been extensively worked as a millstone since the time of the Romans. This lava is a nepheline dolerite, frequently enclosing blue masses of the mineral called Hauyne. The Rhenish millstones are sent down the Rhine to Holland, and were formerly imported into this country under the name of 'Dutch blues.'

MILLSTONE GRIT. A geological term applied to a series of coarse sandstone rocks, belonging to the Coal-measure formations. 'The term gritstone is perhaps most applicable to the harder sandstones, which consist most entirely of grains of quartz most firmly compacted together, by a purely siliceous cement. The angularity of the particles cannot be taken as a character, since the rock commonly called *millstone grit* is generally composed of perfectly round grains, sometimes as large as peas, and even larger; the stone then commencing to pass into a conglomerate.'—*Jukes.*

MINERAL ALKALI. Soda was formerly so called.

MINERAL CANDLES. See CANDLES.

MINERAL CARBON. See ANTHRACITE.

MINERAL GREEN. *Scheele's Green.* Arsenite of copper. See SCHEELE'S GREEN.

MINERAL OILS. Several hydro-carbon compounds are known under this name. Generally it is applied to petroleum, and other fluid hydro-carbons which issue from the earth. These will be described under the several heads of NAPHTHA; PETROLEUM; SHALE OIL.

Lately the mineral oils of Puxière La Grose and Cordessa have been attracting attention. A few words on those will not be out of place here. They have been examined by Joffre in order to ascertain in what points they differ from the petroleum of America. These oils, obtained by distilling bituminous schists, present at first sight a close analogy with the petroleums. They agree very closely in colour, fluidity, specific gravity, and in boiling point. But on the application of certain reagents a difference is at once recognised. The American petroleums, composed of hydro-carbons of the general formula C^nH^{2n+2}, are not attacked by fuming sulphuric acid, and monohydrated nitric acid does not form with them nitro-compounds. On the other hand, if our mineral oils are treated with the former of these agents, about the half is absorbed. If they are acted on by the second, about the half also is attacked with formation of nitro-compounds. These oils, therefore, are composed of a mixture of several bodies, some of which resist sulphuric and nitric acids while the others are attacked by them. Both these portions have been studied. The oils were first purified by rectification over sodium; and they were then divided by fractional distillation into several groups according to the boiling-point. The portion not attacked by fuming sulphuric acid presents all the reactions of the saturated or formenic hydro-carbons, C^nH^{2n+2}. It resists the action of the most energetic reagents. Neither fuming nitric acid nor a mixture of nitric and sulphuric acids attacks it in the cold. At a boiling heat, however, it is attacked, under formation of acid products which remain dissolved in the excess of oil. The boiling-points and specific gravities correspond with those of the saturated hydro-carbons. Elementary analysis gives results which point to the general formula C^nH^{2n+2}. This part of the mineral oils, is therefore, formed of saturated or formenic hydro-carbons. They seem either identical or at least isomeric with those which Pelous and Cahours extracted from the American petroleums. By acting upon portions of the oil with more or less elevated boiling-points each of the hydro-carbons of the saturated series is obtained, from the hydride of octyle C^8H, to the hydride of myristyle $C^{14}H^{30}$. In the portions which distil over at the end we find the hydrides of pentadecyle $C^{15}H^{32}$, of hexadecyle $C^{16}H^{34}$, and of heptadecyle $C^{17}H^{36}$. The proportion of the saturated is about 50 per cent. The portion attacked by acids consists of hydro-carbons of the ethylenic series C^nH^{2n}, mixed with a certain quantity of hydrocarbons still less hydrogenised. These oils contain neither benzole nor naphthalin. At first sight we might be surprised at the absence of the two bodies so generally met with among pyrogenous products. But on further reflection we cannot help admitting that this is quite natural. The manufacturer of mineral oils seeks to distil the schists at the lowest possible temperature in order to avoid the formation of gas and to secure the largest possible yield of oil.

The following facts cannot be too widely known:—

A number of patents have been taken out in different countries for 'inexplosive' gazoline, naphtha, and benzine. Oils of this nature, quite as dangerous as they were originally, before the patented treatment, are sold under such names as 'liquid gas,' 'Aurora oil,' 'safety gas,' 'puroline,' 'petroline,' 'black diamond,' 'septoline,' &c. They are mere mixtures of the ordinary light explosive oils, with roots, gums, barks, and salts. The following are some of the mixtures, as recorded in the Patent List of 1866:—

No. 57,095. Gazoline, 40 gallons; gum olibanum, 1 lb.; cascarilla bark, ½ lb.; lichen, (probably Iceland moss), ½ lb.

No. 57,390. Bark of white oak, 2 lbs.; alkanet root, 2 lbs.; salt, 2 lbs.; alcohol, ½ litre; cyanide of potassium, 30 grammes; to be added to 3 gallons of naphtha.

No. 57,749. Naphtha, 40 gallons; carbonate of soda, 3 lbs.; alum, 2 lbs.; hydrate of lime, 2 lbs.; red ash, 2 lbs.; camphor, ½ lb.; oil of saffron, 12 grammes; essence of tar, 30 grammes.

No. 58,180. Naphtha, 40 gallons; potatoes, 50 lbs.; lime, 4 lbs.; salt of soda, 4 lbs.; turmeric, 3 lbs.

No. 58,905. Gazoline, 40 gallons; salt of soda, 1 lb.; cream of tartar, 1 lb. If the oil of *Gautheria procumbens* is added the offensive odour of the mixture is said to be quite overcome.

No. 59,797. Gazoline, 40 gallons; sulphur, 5 lbs.; rust of iron, 100 lbs.; onions, 1 bushel; resin, 5 lbs.

No. 60,559. Naphtha, 40 lbs.; caustic soda, 1 lb.; alum, 1 lb.; salt 1 lb.; manganese, 30 grammes; water, 120 grammes.

None of these additions can have any effect, save to disguise the colour or smell of the oils, and to diminish their utility, when burnt in a lamp, by clogging up the wick. They cannot in the least obviate their explosive nature. This will be at once apparent, if we reflect that it is not the oil itself which explodes, but merely its vapour, when mixed with a certain proportion of oxygen or of common air. Hence an oil is called explosive when it gives off vapour at low temperatures. That any addition can prevent this escape of vapour without occasioning a complete decomposition of the oil is impossible.

These dangerous and deceptive oils are palmed off upon dealers and consumers by a very ingenious stratagem. It is not generally known that the vapour of a volatile oil or other hydro-carbon requires to be mixed with a very considerable proportion of air to form an explosive mixture. Eight or nine measures of air to one of the vapour is the most explosive proportion, while a mixture of equal parts burns quietly without any explosion at all. In fact, to produce at will the most explosive mixture requires both dexterity and experience, while it is very easy to avoid its generation entirely. When it is desired to prove the complete safety of a dangerous oil, its vapour is allowed to mix with a very little air; a lighted match is then thrust in, and as no explosion follows, the oil is recognised as non-explosive, and used as safe till some serious accident makes its insecurity manifest and puts an end to its sale in the district.

Many of the substances added in the above-mentioned patents subside to the bottom of the cask with as little effect as a handful of pebbles or small shot.

MINERAL PURPLE. Purple of Cassius—which see.

MINERAL STATISTICS of the United Kingdom.

Within our limited space, an attempt will be made to show the value of our mineral produce—and to some extent of our metallurgical operations.

Mr. Carne has given a table in the 'Transactions of the Geological Society of Cornwall,' of the production of tin in Cornwall from 1750 to 1837. We adopt this table from 1800 to 1837, after which, until 1848, no exact return could be obtained. From 1848 the progress of tin mining to 1859 is given as a continuation of the same table. From 1860 to 1873 the production of tin ore and metallic tin is given in a separate table.

The following is a complete statement of the produce of the mines and collieries of the United Kingdom in 1873:—

Minerals	Quantities Tons	Cwts.	Value £
Coal	127,080,385	0	47,689,144
Iron Ore	15,577,449	0	7,573,676
Copper Ore	80,188	10	342,708
Tin Ore	14,884	17	1,056,835
Zinc Ore	15,969	0	61,166
Lead Ore	73,400	10	1,130,367
Iron Pyrites	58,924	3	35,485
Manganese	8,671	6	57,766
Salt	1,780,000	0	890,000
Barytes	10,269	11	7,993

Metals obtained from these Ores.

Pig Iron	Tons	6,545,451	£17,999,989
Tin	,,	9,972	1,329,766
Copper	,,	5,240	502,822
Lead	,,	56,035	1,305,622
Silver	Ounces	537,707	134,427
Zinc	Tons	4,471	120,999

Produce of British Tin Mines since 1800.

Years	Tons	Years	Tons	Years	Tons	Years	Tons
1800	2,522	1815	2,941	1830	4,444	1845	...
1801	2,365	1816	3,348	1831	4,300	1846	...
1802	2,669	1817	4,121	1832	4,323	1847	...
1803	2,960	1818	4,066	1833	4,065	1848	6,613
1804	3,041	1819	3,315	1834	2,989	1849	6,952
1805	2,785	1820	2,990	1835	4,228	1850	6,729
1806	2,905	1821	3,373	1836	4,054	1851	6,143
1807	2,465	1822	3,278	1837	4,790	1852	6,287
1808	2,371	1823	4,213	1838	5,130	1853	5,763
1809	2,548	1824	5,005	1839	...	1854	5,947
1810	2,036	1825	4,358	1840	...	1855	6,000
1811	2,385	1826	4,603	1841	...	1856	6,177
1812	2,373	1827	5,565	1842	...	1857	6,582
1813	2,324	1828	4,931	1843	...	1858	6,920
1814	2,611	1829	4,434	1844	...	1859	7,100

Mr. Carne again informs us that the prices paid to the tinner in Cornwall, between the years 1746 and 1781, varied from 60*s.* the cwt. to 72*s.* the cwt. In a Report of a Select Committee of the House of Lords, on the state of the British Wool Trade, is a table compiled by Edward Charles Hohler, giving the average prices of several articles, amongst others of tin, from 1783 to 1828 inclusive. From this table the following extract is made:—

	£	*s.*	*d.*			£	*s.*	*d.*	
1783 . .	4	1	7	per cwt.	1810 . .	7	9	8	per cwt.
1789 . .	3	10	3	„	1815 . .	7	3	0	„
1794 . .	5	0	3	„	1820 . .	3	15	9	„
1800 . .	5	4	2	„	1825 . .	4	16	6	„

This does not differ materially from the prices given by Mr. Carne as the prices paid to the tinner in Cornwall: the apparent discrepancies arise from the fact, that the above table is the price of tin in the metal market, therefore we have to add, to the price for tin ore, the cost of bringing it into the metallic state.

The value of the metallic tin produced in 1853, when the price varied from 112*l.* to 118*l.* per ton, may be estimated at 700,000*l.* In 1854 the range of prices, not very different from those of the previous year, gives a total value of 690,000*l.* The average prices of 1855 were: English blocks, 125*l.*; bars, 126*l.*; refined, 129*l.* In 1858, the mean average price was 119*l.* per ton. In 1868 it was 98*l.* In 1870 it rose to 127*l.*, and in 1872 to 152*l.* In 1873 it fell again to 133*l.*

Summary of Produce for each Year since 1859, *with the respective Values, &c.*

Years	No. of Mines	Tin Ore		Metallic Tin	
		Quantity	Value	Quantity	Value
		tons	£	tons	£
1860	148	10,400	812,160	6,656	866,306
1861	148	10,963	793,698	7,016	857,706
1862	147	11,841	777,396	7,578	879,048
1863	171	14,224	943,387	9,104	1,065,168
1864	174	13,985	881,031	9,295	995,029
1865	156	14,122	782,284	9,038	873,659
1866	145	13,785	667,999	8,822	781,849
1867	117	11,066	549,375	7,296	670,228
1868	109	11,584	641,137	7,703	756,494
1869	117	13,883	889,378	9,356	1,138,488
1870	147	15,234	1,002,357	10,200	1,299,505
1871	145	13,898	1,068,733	11,320	1,556,557
1872	162	12,300	1,065,658	8,241	1,258,812
1873	217	14,936	1,056,126	10,006	1,334,300

Production of the Dutch Tin Mines since 1855.

This is so important in relation to the British Tin trade, that the preservation of the details is desirable.

Years	Banca[1] slabs		Banca[1] tons	Billiton, estimated slabs		Billiton, estimated tons
1855	128,256	=	4,233	2,734	=	97
1856	201,317	=	6,643	6,714	=	238
1857	149,336	=	4,928	3,674	=	130
1858	192,950	=	6,367	9,014	=	320
1859	181,968	=	6,005	4,620	=	164
1860	165,620	=	5,465	8,000	=	284
1861	173,008	=	5,709	13,018	=	462
1862	141,770	=	4,678	10,182	=	361
1863	191,963	=	6,334	20,636	=	732
1864	161,916	=	5,343	22,380	=	794
1865	138,012	=	4,554	30,000	=	1,065
1866	158,626	=	5,234	33,000	=	1,171
1867	140,570	=	4,639	65,940	=	2,341
1868	120,000	=	3,960	60,600	=	2,151
1869	135,868	=	4,483	68,291	=	2,424
1870	146,000	=	4,672	89,283	=	2,858
1871	134,906	=	4,320	99,700	=	3,190
1872	136,000	=	4,352	108,000	=	3,456
1873	140,000	=	4,480	102,000	=	3,246

[1] 1,000 Banca slabs weigh about 32 tons; the average weight of 1,000 slabs Straits tin being from 35 to 40 tons. The weight of the Billiton slabs is the same as the Banca.

The Quantities of Tin sold in Holland and the Prices realised since 1857.

	Slabs				Per Ton £	s.
1857	190,559		sold at 82¼	Flos. per 50 Kilog.[2]	= 140	10
1858	190,842		„ 68¼	„ „	= 116	0
1859	139,128		„ 88½	„ „	= 141	0
1860	151,513		„ 79½	„ „	= 136	0
1861	149,188		„ 69	„ „	= 118	5
1862	155,193		„ 67¾	„ „	= 115	10
1863	119,092		„ 76	„ „	= 130	0
1864	146,921		„ 61¾	„ „	= 106	0
1865	167,800		„ 56	„ „	= 95	10
1866	111,800	March sale	„ 49¾	„ „	= 87	10
„	109,300	Sept. sale	„ 46	„ „	= 81	10
1867	69,400	March sale	„ 54	„ „	= 94	10
„	71,000	Sept. sale	„ 54¼	„ „	= 95	0
1868	51,100	March sale				
„	90,300	Sept. sale	„ 54½	„ „	= 94	10
„	10,500	Nov. sale	„ 55	„ „	= 95	10
1869	49,500	March sale	„ 82½	„ „	= 142	0
„	61,300	Sept. sale	„ 74	„ „	= 128	10
1870	76,800	March sale	„ 72½	„ „	= 126	10
„	80,000	Sept. sale	„ 75¼	„ „	= 130	0
1871	80,791	March sale	„ 75	„ „	= 129	0
„	83,300	Sept. sale	„ 78¾	„ „	= 136	0
1872	52,800	March sale	„ 96¾	„ „	= 165	0
„	46,500	Sept. sale	„ 92⅛	„ „	= 156	0
1873	75,200	March sale	„ 85	„ „	= 145	0
„	30,000	Sept. sale	„ 75	„ „	= 128	0
„	30,000	Nov. sale	„ 67½	„ „	= 115	0

[2] 50¾ kilogrammes are equal to an English cwt., or 1,015 kilogrammes are equal to an English statute ton.

The Produce of the Copper Mines of Cornwall from the year 1725 *to* 1800, *in periods of ten years.*

Years	Tons of Ore	Average price per ton			Amount realised
		£	*s.*	*d.*	£
From 1725 to 1735 .	64,800	7	15	10	473,500
„ 1735 to 1745 .	75,520	7	8	6	560,106
„ 1745 to 1755 .	98,790	7	8	0	731,457
„ 1755 to 1765 .	169,699	7	6	6	1,243,045
„ 1765 to 1775 .	264,273	6	14	6	1,778,337
„ 1775 to 1785 .	304,133	6	3	0	1,827,106
„ 1785 to 1795[1] .	...		...		...
„ 1795 to 1800 .	249,834	8	9	6	2,177,724[2]

From 1838 the following may be received as an exact statement of the progress of the copper mines of Western England. The accounts are made up to June 30 in each year specified:—

Date	Number of Mines selling Ore	Total of Ore sold		Fine Copper in Ore				Money value			Standard		
		tons 21 cwts.	cwts.	tons 21 cwts.	cwts.	qrs.	lbs.	£	*s.*	*d.*	£	*s.*	*d.*
1838	76	145,688	20	11,527	4	1	17	857,779	11	0	109	3	0
1839	79	159,551	0	12,450	18	1	24	932,297	12	6	110	2	0
1840	79	147,266	0	11,037	16	3	1	792,758	3	6	108	10	0
1841	79	135,090	0	9,987	2	1	23	819,949	2	0	119	6	0
1842	70	135,581	0	9,896	3	0	15	822,870	12	0	120	16	0
1843	64	144,806	0	10,926	1	0	6	804,455	19	0	110	1	0
1844	68	152,667	0	11,246	14	1	20	815,246	9	6	109	17	0
1845	77	157,000	0	12,239	2	3	11	835,358	19	6	103	10	0
1846	88	158,913	0	12,447	16	1	16	886,785	1	6	106	8	0
1847	92	148,674	0	11,966	8	0	18	830,739	9	0	103	12	0
1848	90	155,616	0	12,869	19	1	16	825,080	2	6	97	7	0
1849	89	144,938	0	12,052	17	3	23	716,917	7	0	92	11	0
1850	72	150,890	0	11,824	0	1	21	814,037	3	0	103	19	0
1851	76	154,299	0	12,199	16	1	15	808,244	1	6	101	0	0
1852	82	152,802	0	11,706	16	3	20	828,057	19	6	106	12	0
1853	94	180,095	0	11,839	14	0	0	1,124,561	2	0	136	16	0
1854	96	180,687	0	11,779	14	0	0	1,153,756	3	6	140	2	0

After this period the quantities given are those produced in the year ending December 31.

The following summary for the United Kingdom for the period, ending 1873, will show the falling off in the production of that metal:—

Years	No. of Mines	Copper ore	Value	Copper	Value
		tons	£	tons	£
1863	222	210,947	1,100,554	14,247	1,409,608
1864	201	214,604	1,155,171	13,302	1,350,699
1865	203	198,298	927,938	11,888	1,134,664
1866	173	180,378	759,118	11,153	1,019,168
1867	164	158,544	699,693	10,233	831,761
1868	152	157,335	642,103	9,817	761,602
1869	136	129,953	519,912	8,291	644,065
1870	124	106,698	437,851	7,175	551,309
1871	122	97,129	387,118	6,280	475,143
1872	117	91,893	443,738	5,703	583,232
1873	122	80,188	342,708	5,240	508,822

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[1] The produce of the mines for the years 1789 to 1794 cannot be obtained.

Years . .	1786	1787	1788	1794	1795
Tons . .	39,895	38,047	31,541	42,815	43,589
Amount . .	237,237*l.*	190,738*l.*	150,303*l.*	320,875*l.*	326,189*l.*

[2] This includes the last five years of the last century only.

The earliest accounts of the Swansea sales which we have been enabled to obtain are from 1804, when first the copper sales were published in the 'Cambrian' newspaper. The publication of the printed ticketing-papers commenced in 1839. As these returns show a very remarkable extension of the copper trade of Swansea, the amount sold for each year is given:—

Copper Ores sold at Swansea from the year 1804 *to* 1847.

Date	English	Welsh	Irish	Date	English	Welsh	Irish	Foreign
	tons	tons	tons		tons	tons	tons	tons
1804	...	52	...	1826	505	1,115	4,271	...
1805	...	...	...	1827	508	1,140	7,383	...
1806	...	41	62	1828	320	3,555	8,510	199
1807	...	68	810	1829	720	6,076	7,044	668
1808	...	312	1,391	1830	415	1,788	9,115	934
1809	...	240	530	1831	540	1,442	9,707	975
1810	...	400	603	1832	646	3,184	11,399	641
1811	...	88	68	1833	361	1,786	11,293	1,059
1812	...	622	120	1834	377	3,336	17,280	2,077
1813	...	442	213	1835	268	3,770	22,123	6,758
1814	...	321	429	1836	535	1,698	21,013	9,046
1815	77	1,079	700	1837	179	2,216	22,306	14,521
1816	35	600	673	1838	964	3,410	22,161	19,868
1817	...	422	9	1839	1,812	2,637	23,613	24,092
1818	317	247	349	1840	752	1,525	20,166	35,354
1819	1,796	90	1,531	1841	705	1,180	14,321	41,364
1820	1,408	124	2,200	1842	1,910	857	15,253	44,392
1821	957	191	2,040	1843	756	1,133	17,600	40,739
1822	521	412	1,923	1844	430	700	20,063	45,491
1823	633	564	3,673	1845	622	1,914	19,647	46,643
1824	436	358	4,471	1846	549	1,035	17,533	39,348
1825	2,061	1,191	5,350	1847	406	340	14,373	35,700

The accounts after 1847 were somewhat irregularly kept; but for the ten years ending 1849 the Cornish and Devonshire copper mines sold 1,480,551 tons of copper ore, which produced 114,665 tons of metallic copper. During the same period there were sold at Swansea 6,399 tons of English copper ore, 8,850 tons of Welsh, and 116,182 tons of Irish ore. After that date we are unable to separate in a satisfactory manner the British ores sold at Swansea from the colonial and foreign ores sold in each year. The following Table for each fifth year will, however, fairly represent the Swansea sales of this period.

Years	Ore	Copper				Value		
	tons	tons	cwts.	qrs.	lbs.	£	s.	d.
1850	41,586	7,108	8	1	11	549,258	3	6
1855	43,903	5,926	1	2	14	654,468	11	0
1860	39,658	5,935	5	1	10	566,767	6	6
1865	25,217	3,791	8	1	16	299,352	3	6
1870	14,534	2,329	11	3	4	147,454	11	0

For the last three years the following is a correct statement of the Swansea public sales. Very large quantities of copper ores, principally foreign, were also bought by private contract; the quantities cannot be obtained.

Years	Irish mines ore	English mines ore	Welsh mines ores	Foreign and Colonial ore
	tons	tons	tons	tons
1871	7,795	87	122	17,240
1872	7,809	929	84	10,743
1873	7,003	1,265	4	11,908

Quantities of Iron Ore raised, in each County in England, Wales, Scotland, and Ireland, in the Years 1863 *to* 1868, *and the Aggregate Quantities to* 1873.

	1863		1864		1865		1866		1867		1868		1869	1870	1871	1872	1873
	tons	cwts.	tons	cwts.	tons	cwts.	tons	cwts.	tons	cwts.	tons	cwts.					
Cornwall	18,975	19	34,210	6	36,112	0	18,683	10	6,426	10	8,310	5	11,508,525 tons 14 cwts.	14,370,654 tons 18 cwts.	16,334,888 tons 14 cwts.	15,584,357 tons 2 cwts.	15,294,453 tons 12 cwts.
Devonshire	7,014	0	11,068	0	37,814	5	40,671	0	10,212	10	11,178	1					
Somersetshire	34,709	0	52,925	4	37,984	19	35,323	2	36,874	18	32,450	10					
Gloucestershire	127,497	0	141,843	0	152,710	0	162,129	0	156,169	0	167,288	0					
Wiltshire	72,612	0	79,918	5	77,291	0	75,645	0	82,586	0	75,084	0					
Hampshire	1,400	0	5,100	0	3,525	0	...		...		...						
Herefordshire	4,803	0	6,666	0	...		115	0	...		...						
Oxfordshire	...		...		2,557	0	1,552	0	...		...						
Northamptonshire	126,587	0	335,787	0	364,349	10	476,981	0	416,765	9	449,116	8					
Lincolnshire	69,618	2	74,619	7	124,958	15	175,720	0	192,213	0	205,699	6					
Warwickshire	12,500	0	15,750	0	16,500	0	18,750	0	15,500	0	14,795	0					
Staffordshire	1,531,809	0	1,531,250	0	1,484,991	0	1,211,243	0	1,319,509	0	1,127,459	0					
Shropshire	247,200	0	254,590	0	273,810	0	285,907	0	250,000	0	278,541	0					
Derbyshire	350,500	0	325,600	0	350,000	0	329,500	0	350,000	0	368,440	0					
Yorkshire	3,028,805	18	2,956,890	14	3,337,359	0	3,146,060	0	3,111,038	17	3,590,935	0					
Lancashire	658,642	13	691,321	15	607,439	5	685,726	0	667,356	0	767,025	0					
Cumberland	690,974	15	863,667	0	897,059	18	838,047	0	890,566	0	926,628	0					
Northumberland and Durham	125,000	0	175,500	0	120,000	0	105,000	0	115,700	0	125,000	0					
Monmouthshire	...		...		...		60	0	341,057	0	...						
Wales	448,299	10	497,482	5	485,992	0	425,374	9	545,268	0	712,680	0[1]					
Scotland	1,500,000	0	1,950,000	0	1,470,000	0	1,587,000	0	1,264,800	0	1,250,000	0					
Ireland	31,673	1	60,602	0	29,117	0	25,525	0	42,016	0	41,469	0					
Isle of Man	339	16	...		120	0	...		...		220	0					
Sundries	...		...		355	11	...		...		...						
Total	9,088,960	14	10,064,890	16	9,910,045	17	9,665,012	17	10,021,058	0	10,169,231	10					

[1] And Monmouthshire.

Total estimated value for the United Kingdom in 1862, 2,399,739*l.* 15*s.*; in 1863, 3,240,789*l.* 6*s.* 10*d.*; and in 1864, 3,367,144*l.*

Quantities of Pig Iron, made in each County in England, Wales, and Scotland, in each of the Years 1862, 1863, 1864, *and* 1865.

	1862	1863	1864	1865
ENGLAND :—	tons	tons	tons	tons
Northumberland . . .	46,586	40,916	55,467	49,290
Durham	337,218	468,318	466,980	476,767
Yorkshire	395,519	419,942	521,199	609,654
Derbyshire	131,005	170,026	174,743	189,364
Lancashire	138,563	164,110	195,460	204,925
Cumberland . . .	103,455	106,090	141,033	107,430
Shropshire	125,981	135,557	130,666	117,343
North Staffordshire . .	184,455	176,504	217,996	206,268
South Staffordshire and Worcestershire . . .	410,220	691,157	628,793	629,627
Northamptonshire . .	13,471	14,590	22,823	25,728
Lincolnshire . . .	...	...		
Gloucestershire . .		39,427	65,312	65,471
Wiltshire . . .	51,968	...		
Somersetshire . .	...	24,574		
Total . .	1,938,441	2,451,211	2,620,472	2,738,867
WALES :—				
Denbighshire, &c. . .	31,719	51,076	51,108	51,874
Glamorganshire, *anthracite*	30,375	22,944	26,365	29,213
Caermarthenshire, ,,				
Pembrokeshire, ,,				
Brecknockshire, ,,				
Glamorganshire, *bituminous*	441,869	439,722	461,822	408,213
Brecknockshire, ,,	39,000	35,700	34,260	49,750
Monmouthshire, ,,	385,065	349,387	415,174	357,656
Total . .	925,028	898,829	988,729	916,909
SCOTLAND :—				
Ayrshire	1,080,000	1,160,000	1,158,750	1,163,478
Lanarkshire . . .				
Fifeshire				
Linlithgowshire . .				
Stirlingshire . . .				
Clackmannanshire .				
Haddingtonshire . .				
Argyleshire . . .				
Total . .	1,080,000	1,160,000	1,158,750	1,163,478

The Production of Pig Iron and Estimated Value since 1865.

1866

	Tons	Value
England . .	2,576,928	£11,309,742
Wales . .	952,969	
Scotland . .	994,000	
Total . .	4,523,897	

1867

	Tons	Value
England . .	2,810,946½	£11,902,557
Wales . .	919,077	
Scotland .	1,031,000	
Total . .	4,761,023½	

1868

	Tons	Value
England . .	2,970,905	£12,425,515
Wales . .	931,301	
Scotland . .	1,068,000	
Total . .	4,970,206	

1869

	Tons	Value
England . .	3,465,255	£13,614,397
Wales . .	839,502	
Scotland . .	1,150,000	
Total . .	5,445,757	

1870

	Tons	Value
England	3.735,627	£14,908,787
Wales	1,021,888	
Scotland	1,206,000	
Total	5,963,515	

1871

	Tons	Value
England	4,379,370	£16,667,947
Wales	1,087,809	
Scotland	1,160,000	
Total	6,627,179	

1872

	Tons	Value
England	4,594,614	£18,540,304
Wales	1,057,315	
Scotland	1,090,000	
Total	6,741,929	

Produce of Coal in the United Kingdom since 1864.

Years	Tons	Years	Tons
1864	92,787,873	1869	107,427,557
1865	98,150,587	1870	110,431,192
1866	101,630,544	1871	117,352,028
1867	104,500,480	1872	123,497,316
1868	103,141,157	1873	127,012,767

The following information respecting the distribution of coal in 1871 and 1872 cannot fail to be of interest:—

Summary of Railway and Canal Distribution of Coal in the Years 1871 *and* 1872.

Railways	1871	1872	1872	
			Increase	Decrease
London and North-Western :—	tons	tons	tons	tons
From Cumberland	348,668	384,071	35,403	...
„ Derbyshire	34,355	29,201	...	5,154
„ Staffordshire	763,738	868,774	105,036	...
„ Wales, North	391,516	408,667	17,151	...
„ „ South	104,168	107,520	3,352	...
„ Shropshire	114,586	110,364	...	4,222
„ Warwickshire	202,379	229,105	26,726	...
„ Yorkshire	207,962	235,107	17,145	...
„ Lancashire	5,437,050	5,698,258	261,208	...
„ Cheshire	141,225	133,014	...	8,211
Midland :—				
From Derbyshire	4,595,527	4,875,044	279,517	...
„ Durham	165,484	150,990	...	14,494
„ Lancashire	21,560	22,617	1,057	...
„ Leicestershire	1,017,201	1,162,087	144,886	...
„ Nottinghamshire	574,796	689,407	114,611	...
„ Staffordshire	47,660	53,842	6,182	...
„ Wales, South	8,345	19,440	11,095	...
„ Warwickshire	86,826	119,122	32,295	...
„ Yorkshire	1,503,650	1,637,746	134,096	...
„ Gloucestershire	234,420	232,875	...	1,546
Great Northern :—				
From Derbyshire	11,419	9,471	...	1,948
„ „	375,449	357,580	...	17,859
„ Durham	511,165	409,414	...	101,751
„ Leicestershire	1,827	1,231	...	596
„ Retford	223,420	230,138	6,718	...
„ Wales, South	...	1,082	1,082	...
„ Yorkshire, South	801,504	874,620	73,116	...
„ „ West Riding	490,571	680,068	189,497	...

Railways and Canals	1871	1872	1872	
			Increase	Decrease
	tons	tons	tons	tons
North-Eastern :—				
From Durham, &c.	10,089,217	10,486,168	396,951	...
„ Yorkshire and Lancashire	1,064,407	1,134,542	70,135	...
Manchester, Sheffield, and Lincolnshire	3,173,052	3,740,501	566,448	...
Lancashire and Yorkshire	...	2,874,637	100,000[1]	...
North Staffordshire	1,004,049	1,154,723	50,674	...
Great Western :—				
From Radstock	306,732	261,657	...	45,075
„ Wales, South	2,816,825	3,067,685	250,860	...
„ „ North	839,090	967,855	128,765	...
„ Staffordshire, for London	1,012	11,446	10,434	...
„ „ forwarded	...	494,608	(uncertain)	
Taff Vale	3,593,932	4,213,506	619,574	...
Monmouthshire	1,741,748	1,759,356	17,608	...
Swansea Vale	456,178	494,844	38,666	...
North British	3,600,618	3,797,249	196,631	...
Caledonian	5,014,894	5,229,093	214,199	...
Glasgow and South-Western Canals	1,937,177	2,084,894	147,717	...
Aire and Calder	...	...	16,141[2]	...
Grand Junction	6,615	8,236	1,621	...
Erewash Valley	1,949,428	2,091,377	141,949	...
Birmingham Canal	4,415,697	4,495,333	79,636	...
Staffordshire and Worcester Canal	216,642	214,932	...	1,710
Total increase			4,508,183	202,566
„ decrease			202,566	...
Actual total increase			4,305,617	...

[1] Estimated increase in 1872.

[2] Computed from actual returns.

Shipments of Coal.

	1871	1872	1872	
			Increase	Decrease
	tons	tons	tons	tons
Coal exported to foreign countries	12,747,689	13,198,494	450,505	...
Coal sent coastwise	10,763,289	10,155,858	...	365,450

Details of Shipments.

(Coke in all cases estimated as coal.)

From	1871	1872	1872	
			Increase	Decrease
Northumberland and Durham :—	tons	tons	tons	tons
Foreign	6,712,757	6,248,304	...	464,453
Coastwise	5,387,412	4,737,178	...	650,234
Cumberland :—				
Foreign	3,739	3,288	...	451
Coastwise	599,744	330,425	...	269,319

From	1871	1872	1872 Increase	1872 Decrease
	tons	tons	tons	tons
Yorkshire and Derbyshire:—				
Foreign	666,346	824,163	157,817	...
Coastwise	165,720	271,061	105,341	...
Lancashire and Cheshire:—				
Foreign	701,255	759,446	58,191	...
Coastwise	642,867	630,232	...	...
Gloucester:—				
Foreign	12,919	13,953	1,034	...
Coastwise	232,708	344,450	111,742	12,635
South Wales:—				
Foreign	3,223,944	3,592,767	368,823	...
Coastwise	2,496,711	2,555,805	59,094	...
Scotland:—				
Foreign	1,421,516	1,571,934	150,418	...
Coastwise	1,115,598	1,171,396	55,798	...
Ireland	2,343	511	...	1,832
Ports distant from coalfields:—				
Foreign	106,798	96,230	...	10,568
Coastwise	79,228	120,248	41,020	...
Total increase			1,109,278	202,566
„ decrease			1,409,492	...
Actual decrease on those shipments . .			300,214	...

The difference between this and the 365,450 tons given on the preceding page arises from the deficiency of returns from some of the smaller ports.

The total increase in the quantity of coal carried by railways and by canals in 1872, as compared with that distributed in 1871, *as shown in the returns obtained*, is, as stated, 4,305,617 tons. There are some not very important lines carrying coal, from which returns have not been received; and we have no returns of the quantities carried by carts, or private railways or trams, directly from the pit's mouth to the manufactory, or for the supply of towns. This, however, would not appear to have been largely increased over former years. The following computation of the coal used in our metallurgies, which is based upon information received directly from the smelters and ironmasters, shows that in that direction the increase in consumption has been very small:—

Coal used in Smelting, Refining, Desilverising, &c., of Metals in the United Kingdom.

	1871		1872			
	Ore smelted, and metal obtained	Coal used in smelting and refining	Ore smelted, and metal obtained	Coal used in smelting and refining	Increase	Decrease
	tons	tons	tons	tons	tons	tons
British:—						
Tin ore . .	16,898	35,168	14,266	33,500	...	1,668
Metal . .	11,320		9,560			
Foreign:—						
Tin ore . .	562		1,024			
Metal .	8,583		8,342			

	1871		1872			
	Ore smelted, and metal obtained	Coal used in smelting and refining	Ore smelted, and metal obtained	Coal used in smelting and refining	Increase	Decrease
	tons	tons	tons	ons	tons	tons
British:—						
Copper ore	97,129	411,912	90,551	379,947	...	31,965
Metal	6,281		5,609			
Foreign:—						
Copper ore	302,495		317,868			
Metal	23,672		21,788			
British:—						
Lead ore	93,965	189,807	83,968	185,762	...	4,045
Metal	69,056		60,455			
Foreign:—						
Lead ore	20,860		14,560			
Metal	64,908		69,941			
British:—						
Zinc ore	17,763	171,920	18,542	199,265	27,345	...
Metal	4,966		5,191			
Foreign:—						
Zinc ore	29,418		32,662			
British:—						
Iron ore	16,334,888	19,881,527	15,582,251	20,225,787	344,260	...
Metal	6,627,179		6,741,929			
Foreign:—						
Iron ore	524,034		955,032			
Bar or merchant iron	5,566,175	18,648,686	5,409,203	18,320,830	...	327,854
Total of increase and decrease					371,605	365,532
Actual increase in the coal consumed in the above metallurgies in 1872					6,073	

The consumption of coal in the iron manufacture is computed, upon the information furnished to the Royal Coal Commission, at the rate of three tons of coal used, for all purposes, to each ton of *pig-iron* produced. For the year 1872 the Mining Record Office sought and obtained returns of the coal used for nearly all the blast-furnace establishments. As the result of the economy which has been rigidly pursued since the advance in the price of coal, we have only 51 cwts. of coal given as used for each ton of pig-iron produced. This will give the *quantity used in* 1872 as 17,191,918 tons only. As it is probable that the quanity given in 1871 is in excess, both years have been computed in the Table at the same rate, for strict comparison.

The returns of coals produced, as given by the inspectors, differ from those which appear in the mineral statistics for 1872, as shown below, by the addition of the coal raised in Ireland:—

Years	Coal raised in the United Kingdom	Increase	Coal raised in Great Britain (Inspector's Return)	Increase
	tons	tons	tons	tons
1871	117,352,028	...	117,439,251	...
1872	123,497,316	6,172,288	123,393,853	5,954,602

It has been shown that the increased quantity of coal carried by the railways is above 4,305,617 tons. It is thought, however, that the following estimation, made with great care, will have a very close approximation to the truth, as showing the total increase:—

	Tons
Railways and canals, 1872, increased . .	4,600,000
Exports, 1872, increased	450,505
Iron and other metallurgies, 1872, increased .	6,073
The quantities used at collieries and in mines, *estimated* increase	10,000
Coal carted, or sent by private rail- or tram-roads, to iron-works, manufacturers, and towns, which does not appear in the above returns, *estimated* increase.	250,000
	5,316,578
Coastwise shipments, decrease	300,214
Actual *estimated* increase in 1872 over the production of 1871	5,016,364

Production of the principal Minerals raised in the United Kingdom during the four years ending 1872. *For* 1873, *see* p. 246.

	1869	1870	1871	1872
	tons	tons	tons	tons
Coals	107,427,557	110,431,192	117,352,028	124,497,316
Iron ore . . .	11,508,525	14,370,654	16,334,888	16,584,857
Tin „	14,725	15,23	16,272	14,266
Copper „	129,953	106,698	97,129	91,983
Lead „	96,866	98,176	93,965	83,968
Zinc „	15,533	13,586	17,736	18,542
Pyrites	75,948	58,428	61,973	65,916

MINERAL TALLOW. See HATCHETTINE.

MINERAL WATERS. See SODA-WATER; and WATER.

MINES. (*Bergwerke*, Ger.) The miner, in sinking into the earth, soon opens up numerous springs, whose waters percolate into the excavations which he digs. When his workings are above the level of some valley and at no great distance, it is possible to get rid of the waters by leading them along an *adit-level* or *gallery of efflux*. This forms always the surest means of drainage; and, notwithstanding the great outlay which it involves, it is often the most economical. Many adit-levels are several miles in length, and are so contrived as to discharge the waters of several mines, as in the Gwennap district of Cornwall, and in the environs of Freiberg, in Saxony. Such an amount of slope should be given them as is barely sufficient to make the water run, at the utmost from $\frac{1}{200}$ to $\frac{1}{400}$, so as to drain the mine to the lowest possible level.

Whenever the workings are extended below the natural means of drainage, or below the level of the plain, recourse must be had to mechanical aids. In the first place, the quantity of percolating water is diminished as much as possible by planking, walling, or *tubbing*, with the greatest possible care, those pits and excavations which traverse the water-levels; and the lower workings are so arranged that all the waters may unite into *sumps* or wells placed at the bottom of the shafts or inclined galleries; whence they may be pumped up to the day, or to the level of the *gallery of efflux*. In most mines simple lifting-pumps are employed, but in those districts where the necessity of raising large volumes of water from great depths has led to improvement, forcing-pumps or *plunger*-lifts are introduced, placed over each other at intervals of from 180 to 240 feet, although, for convenience, a lifting-pump or *drawing-lift* occupies the deepest extremity of the shaft, whence it raises the water to the first plunger, and that again forces the stream upward through the column, or *trees*, to the one next above it, and so on up to the adit-level, or to the surface.

These draining-machines are set in motion by that mechanical power which happens to be least costly in the place where they are established. In almost the whole of England, and over most of the coal-mines of France and Silesia, the work is done by steam-engines; in the principal metallic mines of France, and in almost the whole of Germany and Hungary by hydraulic-machines; and in other places, by machines moved by horses, oxen, or even by men. If it be requisite to lift the waters merely to an adit-level, advantage may be derived from the waters of the upper parts of the mine, or even from waters turned in from the surface, in establishing in the adit-level water-pressure machines, or overshot water-wheels, for pumping up the lower water. This method is employed with success in several mines of Hungary, Bohemia, Germany, Derbyshire, Cornwall, in those of Poullaouen in Brittany, &c. It has been remarked, however, that the copious springs are found rather towards the surface of the soil than in the greater depths.

TRANSPORT OF ORES TO THE SURFACE.

The ore being extracted from its bed, and having undergone, when requisite, a first sorting, it becomes necessary to bring it to the day: an operation performed in different ways, according to circumstances and localities, but too often according to a blind routine. There are some few mines at the present day where the interior transport of ore is executed on the backs of men: a practice the most disadvantageous possible, but which is gradually wearing out. The carriage along galleries is usually effected by means of sledges, barrows, or, still better, by little waggons. In many continental countries these consist of frames resting on four wheels; two larger, which are placed a little behind the centre of gravity, and two smaller, placed before it. When this carriage is at rest, it bears on its four wheels, and inclines forwards. But when the miner, in pushing it before him, leans on its posterior border, he makes it horizontal; in which case it rolls only upon the two larger wheels. Thus the friction due to four wheels is avoided, and the roller or trammer bears no part of the burden, as he would do with ordinary wheel-barrows. To ease the draught still more, two parallel rails of wood or iron are laid along the floor of the gallery, to which the wheels of the carriage are adjusted. It is especially in metallic mines, where the ore is heavy and the galleries often crooked, that these peculiar waggons are employed. In coal-mines larger waggons, or frames carrying large baskets, are preferred. The above wain, called on the Continent a *dog* (*chien*, *Hund*), is now often replaced by a larger tram or waggon with flanged wheels, running on edge-rails of wrought iron.

In the great mines, such as many of the coal and salt mines of Great Britain, the salt mines of Gallicia, the copper mines of Fahlun, and the lead mines of Alston Moor, horses have long been introduced into the workings to drag heavier waggons, or a train of waggons attached to one another. These animals often live many years under ground without ever revisiting the light of day, whilst in other cases they are brought to the surface at stated intervals, sometimes daily. In a few of the largest collieries it has been found preferable to establish stationary engines under ground, which bring the train of waggons, by means of an endless rope, along the galleries to the bottom of the shaft. In other mines, such as those of Worsley in Lancashire, subterranean canals are cut, upon which the mineral is transported in boats.

When the operations of a mine are commencing, and the works are of little depth, and employ few men, it is sufficient to place over the shaft a simple windlass, by means of which a few hands may raise the water-barrels and tubs or kibbles filled with stone or ore; but this method soon becomes inadequate, and must be replaced by ***horse-whims*** or more powerful machines.

ACCESSORY DETAILS.

Few mines can be travelled entirely by means of galleries: more usually there are shafts for mounting and descending. In the pits of many mines, especially of collieries, the men go down and come up by means of the machines which raise the mineral. In some mines of Mexico, Northern England, and the North of Europe, pieces of wood, fixed into each side of the pit, form the rude steps of a ladder by which the workmen pass up and down. In other mines, steps are cut in the rock or the mineral, as in the quicksilver mines of Idria and the Palatinate, in the salt mines of Wieliczka, and some of the silver mines of Mexico. In the last, as in the East, they serve for the transport of the ore, which is carried up on men's backs. Lastly, some mines, as in the Austrian Alps, are descended by means of sloping timbers, some of which have an inclination of more than 30°. The workmen in sliding down, in a sitting position, regulate the velocity of the descent by holding a cord, which is fixed along the upper side or roof of the inclined shaft. For description of machines used to facilitate the ascent and descent of miners in shafts, see MAN-ENGINE.

Miners derive light from candles or lamps. They carry the former in a lump of moist clay, or in a kind of socket, terminated by an iron point, which serves to fix it to the side of the excavation, or to the timbering. The lamps are made of iron, tinplate, or brass, hermetically closed, and so suspended that they may not readily droop or invert, and spill the oil. They are generally hung on the thumb by a hook, so as to leave the rest of the hand at liberty for climbing. Miners also employ small lanterns suspended from a button-hole or from the girdle. Many precautions and much experience are requisite to enable them to carry these lights in a current of air, or in a vitiated atmosphere. It is especially in coal mines liable to the disengagement of carburetted hydrogen, or *fire-damp*, that measures of precaution are indispensable against explosions. The appearance of any halo round the flame must be carefully watched, as indicating danger, and the lights should be carried near the bottom of the gallery. The great protectors against these deplorable accidents are ventilation and the safety-lamp. See SAFETY-LAMP.

We cannot conclude this general outline of the working of mines without giving some account of the miners. Most men have a horror at the idea of burying themselves, even for a short period, in these gloomy recesses of the earth. Hence mining operations were at first so much dreaded, that in early times they could only be carried on by the employment of slaves. This dislike has diminished in proportion to the improvements made in mining; and finally, a profitable and respected source of gain, requiring a more than average exercise of skill and intellect, has given mining its proper rank among the other branches of industry; and that *esprit de corps*, so conspicuous among seamen, has also arisen among miners, and adds dignity to their body. Like every society of men engaged in perilous enterprise, and cherishing the hopes of great success, miners get attached to their profession, which, as they advance in intelligence, they regard with pride, and eventually in their old age they look upon other occupations with something like contempt. They form in certain countries, such as Germany and Sweden, a body formally constituted, which enjoys considerable privileges; and the disgrace of being ejected from that body appears to exert in those countries a good moral influence. Miners work usually for eight hours at a time, this being called a *core* or *shift* (*poste* in French, *Schicht* in German).

Miners wear in general a hat or cap capable of withstanding a blow, and a dress suited to protect them as much as possible from the annoyances caused by water, mud, or strong draughts of air. One of the most essential parts of the costume of the German miner is an apron of leather, fitted on behind, so as to protect him when seated on a moist surface or on angular rubbish. In England the miners mostly wear flannel next to the skin, though they frequently in deep mines strip off all their clothes except their trousers. In most countries the hammer and small pick or wedge, the instruments with which before the employment of gunpowder all mining was performed (called in German, *Schlägel* and *Eisen*), disposed in a St. Andrew's cross, are the badge of miners, and are engraved on their buttons, and on everything belonging to mines.

Many of the enterprises executed in mines, or in subserviency to them, occupy a distinguished rank in the history of human labours. Several mines in the Hartz, in Bohemia, and in Cornwall, have been worked to a depth of above and near 2,000 feet; those, indeed, of Kuttenberg in Bohemia are said to have penetrated to 3,000 feet below the surface of the soil.

A great many descend beneath the level of the ocean; and a few even extend far under its billows, and are separated from them by a thin partition of rock, which allows their noise and the rolling of the pebbles to be heard.

In 1792 there was opened at Valenciana in Mexico, an octagonal pit, fully 7½ yards wide, destined to have a depth of 560 yards, to occupy 23 years in sinking, and to cost 240,000*l.*

The great drainage-gallery of the mines of Clausthal, in the Hartz, is 11,377 yards, or 6½ miles long, and passes upwards of 300 yards below the church of Clausthal. Its excavation was commenced at thirty different points, lasted from the year 1777 till 1800, and cost about 66,000*l.* This adit, known as the *Georg Stolln*, having been found inadequate to the drainage of the mines, a deeper gallery was commenced in 1851. This deep adit, known as the *Ernst August Stolln*, was completed in 1864, at a cost of 85,500*l.* The *great adit* (which drains so many of the important mines in the parish of Gwennap in Cornwall to the depth of from 30 to 60 fathoms) amounts, with its branches, to 30 miles in length. Several other galleries of efflux might also be adduced as remarkable for their great length and expense of formation.

The coal and iron mines subservient to the iron-works of Mr. Crawshay, at Merthyr-Tydvil, in Wales, has given birth to the establishment, interiorly and above ground, of iron railways, whose total length, many years ago, was upwards of 100 miles.

The carriage of the coal extracted from the mines in the neighbourhood of Newcastle to their points of embarkation is executed almost entirely, both under ground and on the surface, on iron railways, extending over some thousands of miles.

There is no species of labour which calls for so great a development of power as that of mines; and accordingly it may be doubted if (with the exception of some few engines for the large ocean-steamers) man has ever constructed machines so powerful as those which are now employed for the working of some mineral excavations. The waters of several mines of Cornwall are pumped out by means of steam-engines, whose force is equivalent, in some instances, to the simultaneous action of many hundred horses.

GENERAL SUMMARY OF MINES.

Mines may be divided, generally, into three great classes:—1. Mines in unstratified rocks and the geological formations anterior to the coal strata. 2. Mines in the carboniferous and secondary formations. 3. Mines in alluvial districts.

The first are opened, for the most part, upon veins, masses, and metalliferous beds.

The second, on strata of combustibies, as coal; and metalliferous or saliferous beds.

The last, on deposits of metallic ores, disseminated in clays, sands, and other alluvial matters, geologically superior to the chalk and tertiaries, and of far more recent formation.

The mines of these three classes, placed for the most part in very different physical localities, differ no less relatively to the mode of working them, and their mechanical treatment, than in a geological point of view.

The progress of geological science, however, shows that these divisions cannot be so definitely made as was formerly supposed, and that same of the rocks which were considered to be very ancient, are, in fact, among the more modern of the secondary strata. Thus, most of the metalliferous formations of the Andes, and of Hungary, ought, in strictness, to be classed with the upper secondary, or even the tertiary strata, although they have often been so metamorphosed as to present an appearance very similar to the older rocks.

The following grouping, it will be understood, refers the mines to physical and not to political boundaries:—

MINES OF THE HARTZ.

The name Hartz is given generally to the country of Forests, which extends a great many miles round the *Brocken*, a mountain situated about 55 miles W.S.W. of Magdeburg, and which rises above all the mountains of North Germany, being at its summit 1,226 yards above the level of the sea. The Hartz is about 43 miles in length from SS.E. to NN.W., 18 miles in breadth, and contains about 450 square miles of surface. It is generally hilly, and covered two-thirds over with forests of oaks, beeches, and firs. This rugged and picturesque district corresponds to a portion of the *Silva Hercynia* of Tacitus. As agriculture furnishes few resources there, the exploration of mines is almost the only means of subsistence to its inhabitants, who amount to about 50,000. The principal towns, *Andreasberg*, *Clausthal*, *Zellerfeld*, *Altenau*, *Lautenthal*, *Wildemann*, *Grund*, and *Goslar*, bear the title of mine-cities, and enjoy peculiar privileges; the people deriving their subsistence from working in the mines of lead, silver, and copper, over which their houses are built.

The most common rock in the Hartz is greywacke. It incloses the principal veins, is associated with clay-slate, Lydian stone, or siliceous slate, and greenstones; and is succeeded in geological order by a limestone referable, with a large proportion of the slaty beds, to the Devonian system. The granite of which the Brocken is formed supports all this system of rocks, forming, as it were, their nucleus.

The veins of lead, silver, and copper, which constitute the principal wealth of the Hartz, do not pervade its whole extent. They occur chiefly near the towns of Andreasberg, Clausthal, Zellerfeld, and Lautenthal; are generally directed from E. to W., and dip to the N.E. in the Andreasberg, and to the S. in the Clausthal district, at an angle of about 80° with the horizon.

The richest silver mines are those of the environs of Andreasberg, among which may be distinguished the Samson and Neufang mines, worked to a depth of 2,740 English feet or 456 fathoms. In the first of them there is the greatest *step* exploitation to be met with in any mine. It is composed of 80 *underhand stopes*, and is more than 650 yards long. These mines were discovered in 1520, and the city was built in 1521. They produce argentiferous galena, with silver ores properly so called, such as red silver ore, and ores of cobalt.

The district which yields most argentiferous lead is that of Clausthal. It comprehends a great many mines, several of which are worked to a depth of above 300 fathoms. Such of the mines as are at the present day most productive, have been explored since the first years of the 18th century. Two of the most remarkable ones are the mine of Dorothea, and the mine of Carolina, which alone furnish a large proportion of the whole net product. The grant of the Dorothea mine extends over a length of 257 yards, in the direction of the vein, and through a moderate breadth perpendicularly to that direction. Out of these bounds, apparently so small, but which however surpass those of the greater part of the *concessions* in the Hartz, there were extracted from 1709 to 1807 inclusively, 883,722 marcs of silver, 768,845 quintals of lead, and 2,385 quintals of copper. This mine and that of Carolina have brought to their shareholders in the same period of time more than 1,120,000*l.* profit; and have besides powerfully contributed by loans without interest to carry on the exploration of the less productive mines. It was in order to effect the drainage of the mines of the district of Clausthal, and those of the district of Zellerfeld adjoining, that the great Adit Levels have been excavated.

Below George III.'s Deep Adit (*Georg Stolln*) a still deeper gallery has been constructed, known as the Ernest Augustus Adit (*Ernst August Stolln*), and to complete the drainage of the mines in this district a water-level is in course of construction, 126 fathoms below the Deep Adit, or about 320 fathoms below the surface.

Next to the two districts of Clausthal and Zellerfeld, and Andreasberg, comes that of Goslar, the most important working in which is the copper mine of the *Rammelsberg*, opened since the year 968, on a mass of copper pyrites, disseminated through quartz, and mingled with galena and blende. It is worked by shafts and galleries, with the employment of fire to break down the ore. This mine produces annually from 1,200 to 1,300 metric quintals (about 275,000 lbs. avoird.) of copper. The galena extracted from it yields a small quantity of silver and a very little gold. The latter metal amounts to only the five-millionth part of the mass explored; and yet means are found to separate it with advantage. The mine of *Lauterburg* is worked solely for the copper, and it furnishes annually nearly 66,000 lbs. avoird. of that metal.

Besides the explorations just noticed, there are a great many mines of iron in different parts of the Hartz, which give activity to important forges and furnaces. The principal ores are sparry iron, and red and brown hæmatites, which occur in veins, beds, and masses.

The territory of Anhalt-Bernberg presents, towards the S.E. extremity of the Hartz, lead and silver mines, which resemble closely those of the general district. They produce annually 33,000 lbs. avoird. of lead.

At the southern foot of the Hartz, at Ihlefeld, there is a mine of manganese.

The exploration of the Hartz mines may be traced back for about 900 years. The epoch of their greatest prosperity was the middle of the 18th century. Their gross annual amount was, in 1808, upwards of one million sterling. Lead is their principal product, of which they furnish annually 100,000 quintals, with 44,000 marcs, or 22,000 lbs. avoird. of silver, about 360,000 lbs. avoird. of copper, and a very great quantity of iron. Some of these mines are worked by the Government, others by companies of adventurers. They are celebrated for the excellence of their mining operations, for the systematic application of the processes for dressing the ores, and for the activity, patience, and skill of their workmen.

The Hartz is referred to especially for the manner in which the waters are collected, and economised for floating down the timber, and impelling the machinery. With this view, dams or lakes, canals and aqueducts, have been constructed, remarkable for their good execution. The watercourses are formed either in the open air round the mountain sides, or through their interior as subterranean galleries. The open channels collect the rain-waters, as well as those proceeding from the melting of snows, from the springs and streamlets, or small rivers that fall in their way. The subterranean conduits are in general the continuation of the preceding, whose circuits they cut short. These watercourses present a development in all, of above 125 miles. The banks of some of the reservoirs are of an extraordinary height. In the single district of Clausthal there are 63 ponds, which supply water to a great number of overshot wheels; of those attached to the mines, 46 wheels are at the surface, 21 and 3 water-pressure engines underground, whilst 50 wheels are applied to the dressing machinery, and 39 to the smelting furnaces.

In the mines of the Upper Hartz alone 5,000 persons are employed.

MINES OF THE EAST OF GERMANY.

We shall embrace under this head the mines opened in the primary and transition territories, which constitute the body of a great portion of Bohemia, and the adjacent parts of Saxony, Bavaria, Austria, Moravia, and Silesia.

Among the several chains of small mountains that cross these countries, the richest in deposits of ore is the one known under the name of the *Erzgebirge*, which separates Saxony from Bohemia on the left bank of the Elbe.

The *Erzgebirge* contains a great many mines, whose principal products are silver, tin, and cobalt. These mines, whose exploration remounts to the 12th century, and particularly those situated on the northern slope within the kingdom of Saxony, have been long celebrated. The school of mines established at Freiberg has been considered the most complete in the world. This is a small city near the most important workings, 8 leagues W.S.W. of Dresden, towards the middle of the northern slope of the Erzgebirge, 440 yards above the level of the sea, in an agricultural and trading district, well cleared of wood. These circumstances have modified the working of the mines; and render it difficult to draw an exact parallel between them and those of the Hartz, which are their rivals in good exploration. They are peculiarly remarkable for the perfection with which the engines are constructed both for drainage and extraction of ores, all moved by water or horses; for the regularity of almost all the subterranean labours; and for the beauty of their *walling* masonry. In the portion of these mountains belonging to Saxony, the underground workings employ directly from 9,000 to 10,000 men, who labour in more than 400 distinct mines, all associated under the same plan of administration.

The silver mines of the *Erzgebirge* are opened on veins which traverse gneiss; and though quite different in this respect from the argentiferous veins of *Clausthal*, *Guanaxuato*, *Schemnitz*, and *Zmeof*, present but a moderate thickness, rarely exceeding a few feet. They form several groups, whose relative importance has varied very much at different periods.

For a long time back, those of the environs of Freiberg have been much the most productive; and their prosperity has been always on the advance, notwithstanding the increasing depth of the excavations. Many of the mines now exceed 220 fathoms in depth, and with a view of relieving them of a part of the height through which the water has to be raised, an Adit Level from the valley of the Elbe at Meissen, a distance of above 18 miles is brought up. The most productive and the most celebrated in the present century have been the mines of Himmelsfürst, Himmelfahrt, and that of Beschertglück.

Among the explorations of the Erzgebirge there are none which were formerly so flourishing as those of Marienberg, a small town situated seven leagues SS.W. of Freiberg. In the 16th century ores were frequently found there, even at a short distance from the surface, which yielded 85 per cent. of silver. The disasters of the Thirty Years' War put a term to their prosperity. Since that period they have continually languished; and their product now is very small.

Our limits do not permit us to describe in detail the silver mines that occur near *Ehrenfriedersdorf*, *Johann-Georgenstadt*, *Annaberg*, *Oberwiesenthal*, and *Schneeberg*. Those of the last three localities produce also cobalt.

The mines of Saint-George near Schneeberg, opened in the 15th century as iron mines, became celebrated some time after as mines of silver. Towards the end of the 15th century, a mass of ore was found there which afforded 400 quintals of silver. On that lump, Duke Albert's dinner was served at the bottom of the mine. Their richness in silver has diminished since then; but they have attained more importance during the last 200 years, as mines of cobalt, than they ever had as silver mines. Saxony is the country where cobalt is mined and extracted in the most extensive manner. It is obtained from the same veins with the silver. Smalt, or cobalt-blue, is the principal substance manufactured from it. A little bismuth is extracted from the mines of Schneeberg and Freiberg. Some manganese is found in the silver mines of the Erzgebirge, and particularly at Johann-Georgenstadt.

The mines of Saxony produce a little argentiferous galena and argentiferous grey copper; but the ores of lead and copper may be regarded almost as only accessory products of the silver lodes, from which 78,000 centner or cwts. of the first of these metals are annually extracted, and 341 cwts. of copper. The actual minerals of silver are the more important ores. They were treated partly by amalgamation, at the excellent establishment of Halsbrücke, which was closed in 1859, and partly by smelting processes, the principal works for which are on the Mulde, near Freiberg. The average richness of the silver ores throughout Saxony is only from 3 to 4 oz. per quintal; viz. nearly equal to that of the ores of Mexico, and very superior to the actual richness of the ores of Potosi. The silver extracted from them contains a little gold. The Saxon mines produced, in 1856, 55,500 lbs. of silver. Of these, the district of Freiberg alone furnished 54,000; and among the numerous mines of that district, that of Himmelsfürst of itself used to produce 10,000 marcs.

Silver mines exist also on the southern declivity of the Erzgebirge, which belongs to Bohemia, at *Joachimsthal* and *Bleistadt*, to the N.E. of Eger. Argentiferous galena is principally extracted from the latter, from lodes in the crystalline slates.

The mines of Joachimsthal have been explored to a depth of 650 yards. They were formerly very flourishing; but in 1805 they were threatened with an impending abandonment. More active operations have recently been commenced; and the minerals raised are various ores of silver, and ores of cobalt, nickel, uranium and bismuth. The ancient mines of Kuttenberg, situated farther east, near Gitschin, have been excavated, according to old authors, to the depth of 500 fathoms, but have long been abandoned.

Mines of silver and lead are also worked in gneiss at Ratiborzitz; Adamstadt, near Budweis, which yielded in 1852, 1,200 marcs of silver; Michelsberg, near Plan; Klostergrab, near Teplitz; and Mies, 25 leagues W.S.W. of Prague, at the base of the Böhmerwaldgebirge, a chain of mountains which separates Bohemia from Bavaria.

The most important in the country, and some of the most flourishing in Europe, are at *Przibram*, 12 leagues S.W. of Prague, at the extremity of the mountains which separate the Beraun from the Moldau. In this district, the argentiferous galena is accompanied by blende, in which the presence of cadmium has been observed. These mines, which are worked with all the newest appliances, and have reached in places above 300 fathoms in depth, yield annually 45,000 marcs of silver, and 20,000 cwts. of lead. The lodes, about 50 in number, are most productive in the greywacke, and course N.E. and S.W.

Gold, which in early times was obtained in large quantity from the rivers of Bohemia, has been extracted from veins in gneiss at Bergreichenstein and at Eule, and in granite at Tok and Mileschow.

The copper ore at present worked in several localities is very unimportant.

Next to the silver mines, the most important explorations of the Erzgebirge are those of tin. This metal occurs in veins, massive, and disseminated in masses of vitreous grey quartz, imbedded in the granite. It is also found in alluvial sands. The most important tin mine of the Erzgebirge is that of Altenberg, in Saxony, which has been working since the 15th century. Some tin is mined also near Geyer, Ehrenfriedersdorf, Johann-Georgenstadt, Scheibenberg, Annaberg, Seiffen, and Marienberg, in Saxony. At Zinnwald it is also found; where the stanniferous district belongs partly to Saxony and parly to Bohemia; important mines also occur in the latter territory at Schlackenwald, Graupen, and Abertham, and slightly productive ones at Platten and Joachimsthal. In several of these mines, particularly at Altenberg and Geyer, fire has been employed for attacking the ore, because its matrix is extremely hard. In almost the whole of them, chambers of too great dimensions have been excavated, whence have arisen, at different epochs, serious sinkings of the ground. One of these may still be seen at Altenberg, which is 130 yards deep, and nearly 50 in breadth. The mines of Abertham are explored to a depth of 550 yards; and those of Altenberg to 330. The tin mines of the Erzgebirge produce annually 2,500 cwts. of this metal.

The tin ores are accompanied by arsenical pyrites, which, in the roasting or calcination that it undergoes, produces a certain quantity of arsenious acid.

The Erzgebirge presents also a great many iron mines, particularly in Saxony, at *Rothenberg*, near Schneeberg, where the lode is of fine hæmatite, and from 12 to 24 feet in thickness. In Bohemia, at Platten, where may be remarked especially the great explorations opened in the vein called the *Irrgang*; at Horzowicz, where an excellent hæmatite is worked; at Ransko, and many other places.

There is also in the Erzgebirge a mine of anthracite (stone-coal) at *Schönfeld*, near Frauenstein in Saxony.

The ancient rock formations which appear in the remainder of Bohemia, and in the adjacent portions of Bavaria, Austria, Moravia, and Silesia, are much less rich in metals than the Erzgebirge. No explorations of much importance exist there.

The *Fichtelgebirge*, a group of mountains standing at the western extremity of the Erzgebirge, between Hof and Bayreuth, contains some mines, among which may be noticed, principally, mines of magnetic black oxide of iron and of antimony.

The N.E. slope of the Riesengebirge (Giant Mountains), which separate Bohemia from Silesia, presents also several explorations. The argentiferous copper mines of *Rudolstadt* and of *Kupferberg* have been stated as producing annually a considerable quantity of copper, and from 600 to 700 marcs of silver; the mine of arsenical pyrites at Reichenstein, in the circle of Glatz, yields also a very small proportion of gold. Chrysopase has been found in the mountain of Kosenitz.

MINES OF THE ALPS AND ITALY.

The mines of the Alps by no means correspond in number and richness with the extent and mass of these mountains. On their western slope, in the department of the High and the Low Alps, several lead and copper mines are mentioned, all inconsiderable and abandoned at the present time, with the exception of some workings of galena, which furnish also a little graphite.

During some of the last years of the 18th century, there was mined at *La Gardette* in the *Oisans*, department of the Isère, a vein of quartz which contained native gold and auriferous pyrites; but the product never paid the expenses, and the mine has been abandoned. The workings were resumed in 1837. See description in *Journal des Mines*, t. xx.

The department of the Isère presented a more important mine, worked with regularity from 1768 to 1815; but it also has been given up; it was the silver mine of *Allemont* or *Chalanches.* The ore consisted of different mineral species, more or less rich in silver, disseminated in a clay which filled the clefts and irregular cavities in the middle of talcose and hornblende rocks. This mine yielded annually, towards the conclusion of the 18th century, as much as 2,000 marcs of silver; along with some cobalt ore. Among the great number of mineral species, which occurred in too small quantities to be worked to advantage, there were native antimony, sulphuret of mercury, &c. In the High Alps the mine of argentiferous galena called *L'Argentière* has been resumed.

From the entrance of the valley of the *Oisans* to the valley of the *Arc* in Savoy, there occur, on the N.W. slope of the Alps, a great many mines of sparry iron. The occurrence of this ore is here very difficult to define. It appears to form sometimes beds or masses, and sometimes veins amid the talcose rocks. Some is also found in small veins in the first course of the calcareous formation which covers these rocks. These mines are very numerous, the most productive occur united in the neighbourhood of *Allevard*, department of the Isère, and of *Saint Georges d'Huretières* in Savoy. Those of *Forneaux* and *Laprat*, in the latter country, are also mentioned. The irregularity of the mining operations surpasses that of the deposits. The mines have been from time immemorial in the hands of the inhabitants of the adjoining villages, who work in them, each on his own account, without any pre-arrangement, or other rule than following the masses of ore which excite hopes of the most considerable profit in a short space of time. What occurs frequently in mines of sparry iron, is also to be seen here, most imprudent workings. The mine called the *Grande Fosse*, at *Saint Georges d'Huretières*, is prolonged, without pillars or props, through a height of 130 yards, a length of 220 yards, and a breadth equal to that of the deposit, which amounts in this place to from 8 to 13 yards; thus a void space is exhibited of nearly 300,000 cubic yards. The sparry iron extracted from these different mines supplies materials to 10 or 12 smelting furnaces, the cast-iron of which, chiefly adapted for conversion into steel, is manufactured in part in the celebrated steel works of *Rives*, department of the Isère. There occurs in some parts of the mines of *Saint Georges d'Huretières* copper pyrites, which is smelted at *Aiguebelle.*

Savoy presents celebrated lead mines at *Pesey* and at *Macot*, 7 leagues to the E. of Moutiers. Galena, accompanied with quartz, sulphate of baryta, and ferriferous carbonate of lime, occurs in mass in talcose rocks. The mine of Pesey was taken up in 1792 by the French Government, which established there a practical school of mines; and in its hands the mine produced annually as much as 440,000 lbs. avoird. of lead, and 2,500 marcs of silver. That of *Macot*, opened a few years ago, has given considerable returns. The mine of copper pyrites of *Servoz*, in the valley of the Arve, may also be mentioned. The ore occurs both in small veins and disseminated in a clay slate; but the exploration is now suspended. Lastly, slightly productive workings of anthracite are mentioned in several points of these mountains and in the conterminous portions of the Alps.

There exist in Piedmont some small mines of argentiferous lead. The copper mines of *Allagne*, and those of *Ollomont*, formerly yielded considerable quantities of this metal. Their exploration is now on the decline. The manganese mines of *Saint-Marcel* have been but feebly developed. Mines of plumbago, little worked, occur in the neighbourhood of *Vinay* and in the valley of *Pellis*, not far from *Pignerol.* Some mines of auriferous pyrites have also been worked in this district of country; among others, those of *Macugnaga*, at the eastern foot of Monte Rosa. The pyrites of this mine afforded by amalgamation only 11 grains of gold per quintal; and this gold, far from being fine, contained $\frac{1}{4}$ of its weight of silver. They became less rich in proportion as they receded from the surface. Several similar mines are working in the valleys of Anzasca, Toppa, and Antrona, in the province of Pallanza; the value of the produce being about 20,000*l.* annually.

The most important mines in this country are those of iron. These generally consist of masses of magnetic oxide of iron, of a nature analogous to those of Sweden; the principal ones being those of Cogne and Traversella, which are worked in open quarries. Some others, less considerable, are explored by shafts and galleries. These ores are reduced in smelting cupolas, and Catalan forges. There are considerably above one hundred refinery hearths. The whole produce is stated to be from 10,000 to 15,000 tons of bar iron.

There is a mine of black oxide of iron, at present abandoned, at *Bovernier*, near Martigny, in the Valais. There is also another iron mine at Chamoissons, in a lofty calcareous mountain on the right bank of the Rhône. The ore presents a mixture of oxide of iron and some other substances, of which it was proposed to make a new mineral species, under the name of Chamoissite.

The district of the Grisons possesses iron mines with very irregular workings, situated a few leagues from *Coire.*

In Tyrol, the mines of Kitzbühel and Röhrerbüchel were formerly worked with great activity, and in the middle of the eighteenth century had attained the depth of 440 fathoms; they were then considered the deepest in Europe, but were soon afterwards abandoned. The ores, copper pyrites, and argentiferous *fahlerz* occurred in clay-slate. The products of some small mines in this locality, certain of which are worked in a secondary limestone (as as Rattenberg), are carried to the foundry of Brixlegg, four leagues from Schwatz. The mines of the Tyrol furnished, on an average of years, towards 1759, 10,000 marcs of silver; at anterior periods, their product had been double; but now it is a little less. This region contains also gold mines whose exploration goes back a century and a half. They occur near the village of Zell, eight leagues from Schwatz. The auriferous veins traverse clay-slates and quartzose-slates. The richer portions contain 16 to 20 loth (at ½ an oz.) of gold in 100 cwts. of vein-stone; the remainder only ½ to ¾ of a loth in the same quantity.

At Borgo near Trient, and Pfundererberg near Clausen, lodes occur in clay-slate and greenstone-porphyry, from which are extracted ores of silver, lead, copper, and zinc. An unimportant occurrence of mercury has also been mentioned in that country, near the *Brenner.*

In the territory of Salzburg there are some copper mines; at Zell am See, Brenn thal, Muhl, and Mitterberg, near Werfen. In the lofty-mountain region near Gastein auriferous lodes have been worked for centuries at the Rathausberg, Sieglitz, and Rauris. From 118 marcs of gold in the earlier part of the century, the annual yield has diminished to 80.

At Leogang and Nockelberg an inconsiderable amount of cobalt and nickel ore is raised.

There are mines of argentiferous copper, some of them also yielding nickel and cobalt, analogous to those of the Tyrol, at Schladming, Feistritz, Walchern, and Kallwang; in Styria; at Gross-Fragant and Arza in Carinthia. In the last-mentioned province, the mines of St. Marein and Saversnig yield considerable quantities of lead; whilst at Agordo, in the Venetian Alps, copper ores are raised on a large scale.

At Radlberg and Lassnigberg, in Carinthia, about 321 cwts. of antimony were annually produced a few years since.

Other lead mines of this portion of the Alps, as those of Bleiberg and Raibl, are worked in limestones belonging to the secondary period.

In the Tyrol and in Salzburg, at Schwartz, Pillersee, Bischofshofen, &c., various ores of iron are worked. But the portion of the Alps most abundant in mines of this metal is the branch stretching towards Lower Austria. We find here, both in Styria and in Austria, a very great number of explorations of sparry iron. The deposits of the ores of sparry iron of Eisenerz, Erzberg, Admont, and Vordernberg, deserve notice. The latter are situated about 25 leagues S.W. of Vienna.

The southern flank of the Alps contains also a great many mines of the same kind, from the Lago Maggiore to Carinthia. Those situated near Bergamo, and those of Wolfsberg, Hüttenberg, and Waldenstein, in Carinthia, are among the more notable.

All these mines of sparry iron are opened in the midst of rocks of different natures, which belong to the old transition district of the Alps. They seem to have close geological relations with those of Allevard.

The branch of the Alps which extends towards Croatia, present important iron mines, in the mountains of Adelsberg, 10 leagues S.W. from Laybach in Carniola.

The iron mines just now indicated in the part of the Alps that forms a portion of the Austrian Empire, supply materials to a great many smelting-works. In Styria and in Carinthia more than 400 furnaces or forges may be enumerated, whose annual product has increased within the last few years from 20,000 to upwards of 100,000 tons of pig-iron. These two provinces are famous for the steel which they produce, and for the good iron and steel tools which they manufacture, such as scythes, &c. Carniola contains also a great many forges, and affords annually about 5,000 tons of iron.

The limestones surmounting the southern slope of the Alps contain also some lead mines; but the quicksilver mine of Idria, situated in Carniola, 10 leagues N.W. of Trieste, is worthy of particular notice. It lies beneath a limestone which everything leads us to refer to the *trias* and Halstatt beds, the most ancient of the secondary limestone; but it is uncertain whether the shales in which the cinnabar occurs, and their underlying limestone, belong to the carboniferous or to an older series. About 2,500 cwts. of quicksilver are produced annually.

There has been worked for a few years a mine of chromate of iron at Gassin, department of the Var.

The Apennines, which may be considered as a dependence of the Alps, present a small number of mines, most of them worked on repositories of ore which have a marked relation to the occurrence of serpentine. Thus a most successful copper mine has been in active operation for some years at Monte Catini, in Tuscany; and in the same district of the Maremme several other localities have been worked for copper, mercury, and antimony.

Before quitting these regions we ought to notice the iron mines of the isle of Elba. They have been famous for 18 centuries; Virgil denotes them as inexhaustible, and supposes them to have been open at the arrival of Æneas in Italy. They are explored by open quarries, working on an enormous mass of specular iron ore, perforated with cavities bespangled with quartz-crystals. The island possesses two explorations, called Rio and Terra Nuova; the last having been brought into play at a recent period. The average amount extracted per annum is 25,000 tons of ore, which are smelted in the furnaces of Tuscany, Liguria, and other parts of Italy, and in the island of Corsica. The island of Sardinia contains many indications of silver, lead, and copper ores; but few important mines have been opened in modern times. Zinc and lead ores are, however, worked in Sardinia.

'In the kingdom of Italy, there are 116 mines in operation, about one quarter of the whole number in the country: 45 are iron, 34 copper, 13 argentiferous lead, 14 auriferous pyrites; the other are, 10 zinc, mercury, nickel, and manganese. The metallurgical works treating Italian ores are 335, subdivided as follow:—Iron works, 299; copper, 21; argentiferous, 10; gold, 2; others, 3. The iron ores of Italy are specular, and oligiste iron ores in the islands of Elba, at Cogne, Valley of Aosta, and Tebro in the Valtelina, besides several deposits in Sardinia; hæmatite at Penedoletto in Valtelina, and Pizzano in South Italy; spathic iron, slightly manganiferous, in the Red Sandstone of the Trias; spathic iron, highly manganiferous, and spathic iron in veins. Of the 45 iron mines in operation, 29 are situated in Lombardy, 8 in Piedmont, 5 in Tuscany; Sardinia, Calabria, and Emilia having the three others. The iron mines employ 1,888 workmen and 324 children. The smelting works are 336 in number, of which 299 are in operation, and 37 closed; the former using a motive-power of 5,588 horses, of which 4,353 are produced by water and 1,190 by steam. Italy has 38 blast-furnaces. The iron works have 2,510 skilled workmen and 5,667 labourers; the former receive 3·05 francs a day, the latter 1·80 franc, and the children 0·80 franc. The number of working days is about 300 a year. There are, besides, three mines of iron pyrites near Turin, for the fabrication of sulphuric acid and copperas.'

MINES OF THE VOSGES AND THE BLACK FOREST.

These mountains contain several centres of exploration of argentiferous ores of lead and copper, iron ores, and some mines of manganese and anthracite.

At *Lacroix-aux-Mines*, department of the Vosges, a vein of argentiferous lead has been worked, which, next to the veins of Spanish America, is one of the greatest known. It is several fathoms thick, and has been traced and mined through an extent of more than a league. It is partly filled with *débris*, among which occurs some argentiferous galena. It contains also phosphate of lead, ruby-silver ore, native silver, &c. It runs from N. to S. nearly parallel to the line of junction of the gneiss, and a porphyroid granite, that passes into syenite and porphyry. In several points it cuts across the gneiss; but it probably also occurs between the two rocks. It has never been worked below the level of the adjoining valley. The mines opened on this vein produced, it is said, at the end of the 16th century 26,000*l.* per annum; they were still very productive in the middle of the last century, and furnished, in 1756, 2,640,000 lbs. avoird. of lead, and 6,000 marcs, or 3,230 lbs. avoird. of silver.

The veins explored at *Sainte Marie-aux-Mines* also traverse the gneiss; but their direction is nearly perpendicular to that of the vein of *Lacroix*, from which they are separated by a barren mountain of syenite. They contain, besides galena, several ores of copper, cobalt, and arsenic; all more or less argentiferous. There is found also, at a little distance from *Saint Mary of the Mines*, a vein of sulphuret of antimony. The mines of *Sainte Marie*, opened several centuries ago, are among the most ancient in France; and yet they have been worked very little below the level of the adjoining valleys.

There has been opened up in the environs of *Giromagry*, on the southern verge of the Vosges, a great number of veins, containing principally argentiferous ores of lead and copper. They run nearly from N. to S., and traverse porphyries and clay-slates. The workings have been pushed as far as 440 yards below the surface. These mines were in a flourishing state in the 14th and 16th centuries; and became so once more at the beginning of the 17th, when they were undertaken by the house of Mazarin. In 1743 they still produced 100 marcs, fully 52 lbs. avoird. of silver in the month.

The mines of *Lacroix*, of *Sainte Marie-aux-Mines*, and of *Giromagny*, are now abandoned · but it is hoped that those of the first two localities will be resumed ere long.

In the mountains of the Black Forest, separated from the Vosges by the valley of the Rhine, but composed of the same rocks, there occur at *Badenweiler* and near *Hochberg*, not far from Freiberg, mines which have at times been actively worked. In the Fürstenberg district, near *Wolfach*, particularly at *Wittichen* and *Schapbach*, there are mines of copper, cobalt and silver. The mines of Wittichen produced, some years ago, 1,600 marcs, or near 880 lbs. avoird. of silver per annum. They supply a manufacture of smalt, and one of arsenical products. A few other inconsiderable mines of the same kind exist in the grand-duchy of Baden, and in Wurtemberg.

Several important iron mines are explored in the Vosges; the principal are those of *Framont*, whose ores are red oxide of iron, with crystalline specular ore, which appear to form veins of great thickness, much ramified, and very irregular, in a district composed of greenstone, limestone and clay-slates. The subterranean workings, opened on these deposits, have been hitherto very irregular. There has been discovered lately in these mines, an extremely rich vein of sulphuret of copper. At *Rothau*, a little to the east of Framont, thin veins of red oxide of iron are worked; sometimes magnetic, owing probably to an admixture of protoxide of iron. These veins run through a granite, that passes into syenite. At Saulnot near Belfort, there are iron mines, analogous to those of Framont.

In the neighbourhood of Ihann and Massovaux, near the sources of the Moselle, veins are worked of an iron ore, that traverse formations of greywacke, clay-slate, and porphyry. Lastly, in the north of the Vosges, near Bergzabern, Erlenbach, and Schenau, several mines have been opened on very powerful veins of brown hæmatite and compact bog ore, accompanied with a little calamine, and a great deal of sand and *dèbris*. In some points of these veins, the iron ore is replaced by various ores of lead, the most abundant being the phosphate, which are explored at *Erlenbach* and *Katzenthal*. These veins traverse the sandstone of the Vosges: a formation whose geological position is not altogether well known, but which contains iron mines analogous to the preceding at *Langenthal*, at the foot of Mount Tonnerre, and in the Palatinate. Many analogies seem to approximate to the sandstone of the Vosges, the sandstone of the environs of Saint Avold (Moselle), which include the mine of brown hæmatite of *Creutzwald*, and the lead mine of *Bleiberg*, analogous to that of Bleiberg, near Aix-la-Chapelle.

At *Cruttnich* and *Tholey*, to the north of Sarrbrück, mines of manganese are worked, famous for the good quality of their products. The deposit exploited at Cruttnich, seems to be inclosed in the sandstone of the Vosges, and to constitute a vein in it analogous to the iron veins mentioned above.

There has been also opened a manganese mine at *Lavelline* near *La Croix-aux-Mines*, in a district of gneiss with porphyry.

In the *Vosges* and the *Black Forest* there are several deposits of anthracite (stone-coal), of which two are actually worked, the one at Zunswir near Offenbourg, in the territory of Baden, and the other at Uvoltz, near Cernay, in the department of the Upper Rhine. There are also several deposits of the true coal formation on the flanks of the Vosges.

MINES SITUATED IN THE SCHISTOSE FORMATIONS OF THE BANKS OF THE RHINE, AND IN THE ARDENNES.

The transition lands, which form, in the N.W. of Germany and in Flanders, an extensive range of hilly country, and culminate in the Hündsruck, the Taunus, the Eifel, and the Westerwald mountains, include several famous mines of iron, zinc, lead, and copper. The latter lie on the right bank of the Rhine, in the territories of Nassau and Berg, at Baden, Augstbach, Rheinbreitbach, and near Dillenburg. That of Rheinbreitbach yielded formerly 110,000 lbs. avoird. of copper per annum, and those of the environs of Dillenburg have more recently furnished annually 176,000 lbs. There are also some mines of argentiferous lead in the same regions. The most remarkable are in the territory of Nassau, such as those of Holzappel, Pfingstwiese, Löwenburg, and Augstbach on the Wied, and Ehrenthal on the banks of the Rhine, which altogether produce 600 tons of lead and 3,500 marcs of silver. To the above, we must add those of the environs of Siegen and Dillenburg, situated in the slaty rock and greywacke of the Devonian system, to which the greater part of the area in question belongs. A little cobalt is explored in the neighbourhood of Siegen, and some mines of the same nature are mentioned in the grand-duchy of Hesse-Darmstadt, and in the duchy of Nassau Usingen.

But iron is the most important product of the mines on the right bank of the Rhine. Veins of hydrous oxide, or brown hæmatite, are explored in a great many points of Hessia, and of the territory of Nassau, Berg, Marck, Tecklenburg, and Siegen, along with veins or masses of sparry iron, and beds of red oxide of iron. We may note particularly: 1. The enormous mass of sparry iron, known under the name of Stahlberg, mined since the beginning of the 14th century in the mountain of Martinshardt, near Müsen; and the numerous lodes of hæmatite, brown oxide and sparry iron, in the same district; 2. The abundant and beautiful mines of hydrous oxide and sparry iron on the banks of the Lahn and the Sayn, and among them the mine of Bendorf; 3. The mine of Hohenkirchen in Hessia, where a powerful bank of manganesiferous ore is worked, and where the mines are kept dry by a gallery more than one thousand yards long, walled over its whole extent. These several mines supply a great many iron works, celebrated for their steel, and for the objects of hardware, scythes, &c., manufactured there. Nassau produces a considerable quantity of first-rate ore annually, most of which is exported.

The Prussian provinces of the left bank of the Rhine, the duchy of Luxembourg and the Low Countries, include also many iron furnaces, of which a great number are supplied, in whole or in part, by ores of hydrous oxide of iron, occasionally zinciferous, extracted from the transition rocks, where they form sometimes veins, and sometimes also very irregular deposits. A portion is explored by open quarrying, and a portion by underground workings. Great activity has within the last few years been imparted to these operations, by the rapid development of the Westphalian coal-field, and the increased manufacture of coke-made iron.

The *Eifel* formerly possessed important lead mines. Some still exist, which are feebly worked at Berncastle, 8 leagues below Trèves, on the banks of the Moselle. Those of Trarbach, situated two leagues lower, are now completely abandoned. The same holds with those of Bleialf, which were opened on veins incased in the greywacke-slate, 3 leagues W.N.W. of Prüm, not far from the line of separation of the waters of the Moselle and the Meuse, in a district from which manufactures and comfort have disappeared since the mines were given up which sustained them. The mine Wohlfahrt, near Rehscheid, produces annually 500 tons of a fine galena, suitable for 'potter's ore.'

More to the north a great many deposits of calamine occur. The most considerable, and the one which for many years past has given the Company working it the command of the zinc trade of the world, is called the *Vieille Montagne* (Altenberg), at Moresnet, between Aix-la-Chapelle and Herbesthal. The mass upon which the works are opened, and in which the calamine is very irregularly intermixed with clay and ochre, is about 450 yards in length and 150 in width: it is situated at the junction of the carboniferous limestones and the slate termed the *schiste anthraxifère*, upon which geological horizon a number of other deposits of a similar character have been found at intervals, with a thickness and richness equally variable. The minerals, brown iron ore, galena, zinc-blende, and iron pyrites occur with the calamine, and the former especially sometimes overpowers it. Among such deposits, many of them largely worked, are Herrenberg near Holberg, Engis, Huy, Verviers, Corphalie, Membach, and some which reappear, after dipping beneath the alluvial valley of the Rhine, in the same geological position, in Westphalia.

The *Vieille Montagne* Company possess other sources of zinc ore in the Prussian and in the Baden territory; and, employing about 7,000 men in all, produce no less than 16,000 tons of zinc from their own mines, besides manufacturing a large quantity purchased from other producers. The *Nouvelle Montagne* Company, Verviers, also work their deposits on a large scale, and increasing success appears to attend the works established more recently on the right bank of the Rhine.

Of the mines in this border district which produce lead, the most important are those of the Stolberg Westphalia Company, yielding annually 5;000 tons of lead, and those of the *Eschweiler* and the *Alliance* Company, also of Stolberg.

A lead mine is opened at Vedrin, N. of Namur, on a vein of galena, nearly vertical, which courses from N. to S. in a limestone in nearly vertical strata. The vein is from 4 to 15 ft. thick, and is recognised through a length of half a league. The mine, worked for two centuries, presents very extensive excavations; particularly a fine Adit Level. From its former annual production of 900 tons of lead it has now sunk to a very small amount.

MINES OF THE CENTRE OF FRANCE.

The ancient formations, principally granitic, which constitute the basis of several departments of the centre and south of France, are hardly any richer in explorations than the districts mentioned at the end of the Black Forest. Many metalliferous veins have been observed in the mountains of the Auvergne, Forez, Cevènnes and Lozère, but very few of the workings have attained to any importance. Most of the mining trials have been made near the eastern border of the mass of primary formations, in a zone characterised by a great abundance of schistose rocks.

At Villefort and Vialas, in the department of the Lozère, and in some places adjoining, several veins of argentiferous galena are worked which traverse the gneiss and the granite. These mines, remarkable at present for the regularity of their workings, employ 300 persons, and produce annually about 1,000 quintals of lead, and about 2,000 marcs of silver.

Pontgibaud has been for some years the centre of mines of argentiferous lead, opened upon a group of north and south lodes intersecting a rock of gneissose granitic character. Explorations have been commenced mostly where these lodes were discovered in the valleys, as at Roure, Rosier, Mioch, Pranal, and Barbecot; and since 1853, by the joint exertions of an English and French proprietary, the mines have been raised to an important position, employing about 1,200 workpeople. An unusual source of difficulty has been presented, in the form of strong emanations of carbonic acid gas from the lode and the fissures of the country, and which renders it necessary to employ powerful ventilating machines, driven by water-wheels. The presence of this gas is evidently connected with the volcanic phenomena of the adjacent district, where streams of recent lava overlie the metalliferous granite, and are not penetrated by the lodes. The Pontgibaud mines yield annnally about 1,500 tons of lead, and 145,000 ozs. of silver.

In the department of the Loire, the lead mines of *St.-Martin-la-Sauveté* south of Roanne have been extensively opened on veins running N.W. and S.E.; they are now in English hands.

The mountains of Ambert, on the west of the valley of the Dore, Saint-Amand-Roche-Savine and Giroux, as well as the mountains above Jumeaux, exhibit veins of somewhat analogous character.

At Malbosc and Bordezac (Ardèche), small lodes of antimony are seen in the slaty rocks.

The city of Vienne, in Dauphiny, is built on a hill of gneiss, separated by the Rhône from the main body of the primitive formations, and in which veins of galena occur, which are now imperfectly mined. Other lead mines of less importance are observed at *St. Julien-Molin-Molette*, department of the Loire, and at *Joux*, dep. of the Rhône.

At *Chessy*, seven leagues N.W. of Lyons, mines, now worked out, were opened upon an irregular deposit of copper ore, occurring at the contact of granite with the lower sandy beds of the lias. The carbonates of copper were especially abundant, and the azurite, or blue carbonate, from this mine is noted for the beauty of its crystallisation. At Sainte-Bel, two leagues S. of Chessy, a very similar deposit of copper pyrites, has also, after many years of activity, been abandoned.

An abundant deposit of manganese ore, very irregularly worked, at Romanèche (Saône-et-Loire) occurs in an analogous geological position; as do also smaller bodies of galena, calamine, and zinc-blende at Figeac, Villefranche, and Lardin.

At Ecouchets, near Couches, the oxide of chromium disseminated in the sandstones termed *arkoses*, has been occasionally worked. Some important veins of zinc-blende have been traced at Clairac, in the department du Gard, for above 1,000 yards from N. to S. in the beds of metamorphic lias. Iron ores of oolitic texture are largely worked in the Jurassic and Neocomian rocks in various parts of France.

Lastly, tin ore, accompanied by wolfram, has been found to occur in small lodes in the district of Limoges, so well known for its china-clay, especially at Vaulry, a few leagues NN.E. of that town; and bismuth has recently been worked at Meymac, in the department of Corrèze.

MINES OF BRITTANY.

In its geological conformation Brittany has a great analogy to its opposite neighbour, Cornwall; but notwithstanding the resemblance of its granites, ancient schists (killas), and porphyries, it bears no comparison in the importance of its mineral repositories. Tin ore has been found at two places, Piriac, a few miles to the N.E. of the mouth of the Loire, where small quartzose veins, containing that mineral, occur at the junction of the granite and schists, and appear to have given rise to the alluvial deposits of tin found near the mouth of the Vilaine; and at Villeder, department of

Morbihan, where a quartzose tin-bearing vein intersects the granite, in the direction E.N.E. and W.S.W., and contains also mispickel, topaz, and beryl. These localities have afforded very fine specimens of tin ore, excellent examples of which appeared at the Paris Exposition in 1855; but although frequent trials have been made upon them, they have not yet led to an extensive and systematic working.

The most important exploitations in this district are the lead mines of *Poullaouen* and *Huelgoat*, situated near Carhaix. The mine of Huelgoat, celebrated for the *plomb-gomme* (hydro-aluminate of lead) discovered in it, is opened on a vein of galena, which traverses clay-slate rocks. The workings have subsisted for about three centuries, and have attained to a depth of 270 meters.

The lode has been followed over a horizontal distance of about 1,000 meters, and contains, besides argentiferous galena, ochreous substances yielding about $\frac{1}{1000}$th of silver in the native state, or as chloride.

The vein of Poullaouen, called the New Mine, was discovered in 1741. It was powerful and very rich near the surface; but it became subdivided and impoverished with its depth, notwithstanding which the workings have been sunk to upwards of 250 meters below the surface. In these mines there are fine hydraulic machines for the drainage of the waters, with wheels from 14 to 15 yards in diameter; and water-pressure machines have been some years since constructed there.

The vein courses through greywacke in a direction N. 22° E., and, including five branches, has in some places reached the width of 60 feet.

The annual produce of these mines is 300 tons of lead and 1,400 kilograms of silver. Several veins of galena exist at *Châtelaudren*, near Saint-Brieuc, but they are not worked at present. There is also one at Pontpéan, near Rennes, which has been worked to a depth of 140 yards, but has in like manner been abandoned. It affords, besides the galena, a very large quantity of blende (sulphuret of zinc), considerable amounts of which, of a very crystalline character, have, during the last few years, been exported. This is also a N.S. lode.

There occurs, moreover, a lead mine at Pierreville, department of the Channel, opened on a vein which traverses limestone. The same department presents a deposit of sulphuret of mercury at Ménildot. A mine of antimony was worked at La Ramée, department of La Vendée.

At Melles (Deux Sèvres), ancient works on argentiferous galena are traceable, of which the date is unknown.

It is, however, evident that these metals are only in part the production of the mines of France proper.

MINES OF GREAT BRITAIN AND IRELAND.

The mines comprehended in this section are situated, 1. in Cornwall, Devonshire, and Somersetshire; 2. in the S.E. of Ireland; 3. in the island of Anglesey and the adjoining part of Wales; 4. in Cumberland, Westmoreland, the north of Lancashire, Yorkshire and Derbyshire, Durham and Northumberland, and the Isle of Man; 5. in the south and west of Scotland.

It will be observed that the metalliferous rocks, analogous to those of the N.W. of France last described, present themselves in the West of England, Wales, and Scotland, striking in a direction of E.N.E. or N.E.; whilst in Ireland, although the same general direction is usually apparent, similar rocks form the surface in many portions of the island.

Cornwall and Devonshire present four principal mining districts: viz. that of the West, including St. Just, St. Ives, Marazion, and St. Erth; secondly, that of the West centre, including Gwennap, Redruth, Camborne, St. Agnes, and Wendron; thirdly, the East centre of St. Austell and Lostwithiel; fourthly, the eastern district, from Liskeard to Tavistock. Again, in Devonshire, there are the mines between Newton and Exeter, and those near North Molton.

The first two of these districts are the most important of the four in the number and richness of their mines of copper and tin. The ores of copper, which consist almost entirely of copper pyrites and vitreous sulphuret of copper, constitute very regular veins, running nearly from east to west, and incased most frequently in a clay-slate locally termed *killas*, and belonging to the Devonian system of modern geologists; but frequently also in the granite, which forms a series of protuberances rising through clay-slates, in an E.N.E. direction from the Land's End to Dartmoor. The tin, besides being found in alluvial deposits or 'stream-works,' which are nearly all worked out, also occurs in veins or lodes which have a general east and west direction, the same held by numerous dykes of granitic porphyry ('elvan'), which appear to have a close relation to the metalliferous veins. The tin ore in a few mines forms also irregular masses (termed *tin-floors* and *carbonas*) which appear most usually attached to the veins by one of their points. Some of the veins present the copper and tin ores together; a mixture which occurs often near the points of intersection of the two metallic veins. Certain mines furnish alternately both copper and tin; but the most part produce only one of these metals, especially Dolcoath and the surrounding mines.

Among the more important mines of the above metals in the western districts may be noticed: Huel Basset, North and West Basset, South Francis, United Mines, Huel Buller, Alfred Consols, Carn Brea, Levant, and Botallack; for tin more especially, Huel Vor, Dolcoath, and Polberro.

In the environs of St. Austell the more remarkable mines were those of Fowey Consols, which was once the deepest-worked mine in Britain, Par Consols, Crinnis, the tin mine of Polgooth, abandoned, and the singular open-cast of Carclaze, worked on numerous small strings of tin, coursing through a granite so decomposed as to be in great part available for china-clay.

North of Liskeard, the Phœnix and Caradon mines have attained, since 1838, a great degree of prosperity; whilst still further east the neighbourhood of Callington is marked by several productive copper mines on a smaller scale, and the large ancient tin mine of Drake Walls. The Tavistock district has been rendered famous by the long-continued successful working of Huel Friendship, and the enormous wealth extracted since 1845 from the series of mines on one great lode, entitled the Devon Great Consols.

There exists also in Cornwall veins running more or less N. and S.; these are lead lodes generally. The 'cross-courses,' which intersect and often dislocate these lodes, sometimes containing only clay (*flucan*) or quartz (*spar*), at other times particular metallic minerals. Thus, near Helston several such veins have been worked for silver-lead ore; at Restormel near Lostwithiel, and in the St. Austell granite, for red and brown oxides of iron: east of Liskeard, at Herodsfoot, Huel Mary Anne, Redmoor, and the Tamar mines, for lead ores containing from 30 to 80 ounces of silver to the ton.

In some few instances, and chiefly in connection with these cross veins, ores of silver, cobalt, and nickel, have been raised; whilst very rich silver ores were obtained some years ago from E. and W. veins, at Huel Vincent, Huel Brothers, &c., near Callington.

Antimony has been raised from mines near Endellion, and at Huel Boys; and manganese is now worked from shallow irregular deposits in the slates at many points in the east of Cornwall, and in Devonshire.

The tin and copper ores of Cornwall are accompanied with arsenical pyrites, which is turned to some account by the production of white arsenic (arsenious acid).

The tin ores are treated at several works situated in Cornwall. All the copper ores are sent to Swansea in South Wales to be smelted; and a part of the lead ores only is reduced at smelting-works near Truro, at Par, and on the Tamar.

In consequence of the great influx of subterranean waters, the mines of Cornwall and Devonshire are worked upon principles somewhat differing from those of many other mining districts, expedition being regarded as one great source of economy. Especially in the application of steam-power to pumping-purposes have the inventive powers of the engineers, in modifying the engines and boilers, and the skill of the miners, in placing the pit-work and pumps, attained a high degree of perfection. For this purpose engines having a cylinder of 80, 90, and even 100 inches in diameter have been erected, employing high-pressure steam expansively.

Many of the mines are explored to a depth of between 1,200 and 2,000 feet; and some are celebrated for the boldness of their workings. Thus several mines, especially Botallack and Levant, in the parish of St. Just, near Cape Cornwall, have their shafts placed close to the edge of the cliffs, and extend several hundred fathoms under the sea, and to depths of from 120 to 240 fathoms beneath its level. At Huel Cock so small a thickness of rock has been left to support the weight of the waters that the rolling of pebbles on the bottom is distinctly heard by miners during a storm. The mine of Huel Werry, near Penzance, was worked by means of a single shaft opened on a reef of rock in a space left dry by the sea only for a few hours at every ebb. A small wooden tower was built over the mouth of the shaft, which, being carefully caulked, kept out the waters of the ocean when the tide rose, and served to support the machines for raising the ore and water. A vessel driven by a storm overturned it during the night, and put an end to this hazardous mode of mining, which has not been resumed.

An important group of veins of lead, often argentiferous, is opened in the slaty rocks of Cardiganshire and Montgomeryshire, all of which have an E. and W. direction, although so far from parallel that they often meet, and frequently form at such points of intersection 'courses' of ore. The galena is accompanied generally by quartz and blende, more rarely by iron pyrites and calcspar. Some of these mines were very profitably worked in the 17th century, and during the last forty years several of them, as Goginan, Cwm Ystwyth, Logylas, and Frongoch, have been highly productive. In 1873 these counties yielded 10,061 tons of metallic lead and 94,826 ounces of silver.

The more complicated geological formations of Carnarvonshire and Merionethshire present, chiefly among the slaty rocks, a number of veins bearing copper, lead, and zinc ores, in which a special point of interest is the occurrence of gold. This metal has been found within the last few years in rich specimens, mostly associated with quartz and blende; but it has not hitherto been remuneratively raised. The veins occur chiefly in two groups, the one to the NN.W. of the town of Dolgelly, the other in the hills around the Bala Lake. Flintshire and Denbighshire produced in 1873 3,712 tons of lead, yielding 23,676 ounces of silver.

The adjacent isle of Anglesey is celebrated for the copper mines of Mona, and the Parys mountain. The ore is copper pyrites, intercalated among slaty rocks and felstone, and near the surface it occurred in enormous mass. The workings have thence been carried on as open casts; but beneath these, again, regular subterranean operations have been conducted, although the veins there show themselves small, and comparatively poor. Large quantities of copper are here obtained by precipitation from the mine-water, and the various ores are treated at furnaces situate at Amlwch. The Isle of Man has two important lead mines, the Foxdale and Laxey; the former remarkable for the great size of its main lode, and the occasional high percentage of silver; the latter for its crystalline blende. Ten mines produced lead in 1873, three copper, and four zinc ore.

The slates of Cumberland and Westmoreland yield lead ores, and a small quantity of copper ore. At Borrowdale, near Keswick, a mine of graphite (plumbago) has been worked for a long period. It furnishes the black-lead of the English pencils, so celebrated over the world. The mineral occurs in irregular lumps and nests, in a variety of greenstone rock. Coniston copper mine in Lancashire is specially notable. The lead mines of Durham and Northumberland are also very productive; the total produce of those countries in 1873 being 16,864 tons of lead. The lead mines of Yorkshire produced in the same year 3,704 tons.

There are famous lead mines in the south of Scotland, at Wanlock-head, in Dumfriesshire and Leadhills in Lanarkshire, the veins of which occur in Silurian rocks. At Cally, in Kirkcudbrightshire, copper ore has been discovered; and a mine of antimony has been known in Dumfriesshire; but neither has been turned to good account.

In the middle part of Scotland the lead mines of Strontian in Argyleshire deserve to be noticed. A lead mine in schist has been also worked by the Marquis of Breadalbane at Tyndrum. In the Isle of Islay lead is being worked.

The produce of the Scotch lead mines in 1873 was 2,150 tons of lead.

In Ireland the Berehaven and the Knockmahon mines have, with great profits to the adventurers, for many years past produced large quantities of copper ore. In 1873 7,003 tons of ore were sold. Copper ores are also worked at the Ballycummisk mine, Co. Cork, and at Connorree and four other mines.

Among the other mines of Ireland are those of Ballygahan and Tigrony, and of Ballymurtagh, situated 3 leagues S.W. of Wicklow. Their object is to work pyrites, accompanied with some poor ores of copper, galena, sulphide of antimony. Iron pyrites, since 1840, has been a large article of export, amounting in some years to from 60,000 to 100,000 tons. In 1873 the ores of Wicklow amounted to 40,063 tons only.

The granite of Wicklow also contains some lead mines. Luganure and Glendalough were the only mines worked in 1873.

In the south-west of Ireland indications of copper and lead ores have been met with at many other points, but no important mines have yet been opened upon them.

An Irish correspondent, writing on the iron ores which are now largely worked in the north of Ireland, states that at Carrlough immense quantities of iron ore and limestone are shipped. The former, which is not of the best quality, is carried to Seaham, there to meet the coal from the mines on Lord Londonderry's estate. A railway is being constructed from Red Bog to the top of Glenariff. This undertaking, which will cost 50,000*l.* to 60,000*l.*, is entirely in the hands of an English company, and will be used only for the transit of iron ore. Close to Red Bog is a wire tramway, the property of the Antrim Iron Ore Company. It has four stationary engines along its route to work it, and extends a distance of 6 miles. At Red Bog three distinct companies are employed shipping iron ore, which is of a very superior quality, and contains over 50 per cent. of pure iron. The bleak moorland at Glenravel is now varied by the numerous mouths of tunnels driven into hills, which appear as if they were composed of iron ore in inexhaustible abundance. A great part of the iron mountains belong to Lord Antrim. The companies pay large sums annually for their leases, besides royalties of 6*d*. a ton on all ore shipped. The miners' wages are by no means high; at Red Bog the English company gives 14*s*. and the Antrim Iron Ore Company, 15*s*. per week. In 1873 these iron mines produced 138,765 tons of iron ores.

MINES OF THE PYRENEES.

The Pyrenees and the mountains of Biscay, of the Asturias, and the north of Galicia, which are their prolongation, are not very rich in deposits of ores. The most important mines that occur there are of iron, which are widely spread throughout the whole chain, except in its western extremity. We may mention particularly in Biscay the mine of *Sommorostro*, opened on a bed of red oxide of iron; and in the province of Guipuscoa, the mines of Mondragon, Oyarzun, and Berha, situated on deposits of sparry iron. There are several analogous mines in Aragon and Catalonia. In the French part of the Pyrenees veins of sparry iron are worked, which traverse the red sandstone of the mountain Ustelleguy, near Baygorry, department of the Basses-Pyrenees. The same department affords in the valley of Asson the mine of Haugaron, which consists of a bed of hydrate of iron, subordinate to transition limestone. The deposit of hydrate of iron, worked for an immemorial time at *Rancié*, in the valley at Vicdessos, department of the Arriège, and averaging 60 feet in thickness, occurs in a limestone now regarded as of the age of the lias. The ancient workings have been very irregular and very extensive; but the deposit is still far from being exhausted. There are also considerable mines of sparry iron at *Lapinouse*, at the tower of Batera, at Escaron, and at Fillols, at the foot of the *Canigou*, in the department of the Oriental Pyrenees. The iron mines of the Pyrenees keep in activity 200 Catalonian forges. Although there exists in these mountains, especially in the part formed of transition rocks, a very great number of veins of lead, copper, cobalt, antimony, &c., one can hardly mention any workings of these metals; and among the abandoned mines, the only ones which merit notice are, the mine of argentiferous copper of *Baygorry*, in the department of the Low Pyrenees, the lead and copper mines of *Aulus*, in the valley of the Erce, department of the Arriège, and the mine of cobalt, of the valley of Gistain, situated in Aragon, on the southern slope of the Pyrenees. The mines of plumbago opened at Sahun in Aragon should not be forgotten. Analogous deposits are known to exist in the department of the Arriège, but they are not mined.

Previous to the discovery of America, considerable workings were carried on in auriferous sands at various points in this department. A gold mine has also been wrought, but without success, near Cabo de Creua, on the Spanish side.

MINES OF SPAIN AND PORTUGAL.

The granite, gneiss, and slaty formations of the Iberian Peninsula, noted in early times for their mineral wealth, have during the last 40 years again become the scene of important mining operations. The region of the Sierra-Morena, comprising parts of the provinces of Andalusia, Estremadura, and La Mancha, forms one of those primary districts which offer close analogies with some of the mining localities already described; and exhibits numerous mines now in activity, and the traces of former extensive operations.

The noted quicksilver mines of Almaden, producing about 2,000 tons per annum, are worked on three parallel veins of from 6 to 12 meters in width, lying conformably with highly-inclined Silurian strata.

The silver mines of Guadalcanal and Cazalla, north of Seville, in mica slate, were very rich in the time of the Counts Fugger, but are now inconsiderable; this territory presented formerly important mines at Villa-Guttier, not far from Seville. At the beginning of the 17th century they are said to have been worked with such activity that they furnished daily 170 marcs of silver.

In the limestones near Santander were very important mines of calamine, but these have not been worked recently (1874).

More to the east there exists in the mountains of La Mancha a mine of antimony at Santa-Crux-de-Mudela. On the southern slope of the Sierra-Morena very important lead mines occur, particularly at Linares, 12 leagues N. of Jaen. The veins are very rich near the surface, whence the ground is riddled, as it were, with shafts. More than 5,000 old and new pits may be counted; the greater part of which is ascribed to the Moors.

Systematic workings have been for some years carried on by English companies at some of these mines, with excellent results; and, with the aid of steam-engines, a depth of 80 or 90 fathoms has now been attained.

The lodes, which have a medium width of 3 or 4 feet, course generally NN.E.

dipping towards the N.W., and traverse a granite, which on the outskirts of the district is overlaid by clay-slates and sandstone, also penetrated by the veins. The galena is accompanied by barytes in large quantity, and, in greater depth, by calcspar. A single mine, that of Pozo Ancho, raises 500 tons of lead ore per month.

At Rio Tinto, near Seville, a massive deposit of iron pyrites, 50 *varas* in width, has been worked, chiefly for the copper pyrites which is mingled with it. The cupriferous iron pyrites, which occurs in large deposits in the south-west of Spain and in Portugal, is now very largely worked; the pyrites being first burnt for its sulphur, and then treated by the wet way for extraction of copper. See Pyrites.

Abundant mines of zinc ores occur near Alcaraz, 15 leagues N.E. of Linares; which supply materials to a brass manufactory established in that town. There are also lead mines in the provinces of Murcia and Grenada. Very productive ores have been worked for some time in the Sierra de Gador near Almeria, a harbour situated some leagues to the W. of the Cape de Gata, and also near Cartagena. A fine silver lode has been worked to a depth of 110 fathoms, at Almagrera.

In Murcia, Grenada, and Cordova, there are also several iron mines, and near Marbella and Ronda, in Grenada, mines of plumbago are explored.

Among the most remarkable mines of Spain are those of silver at Hiendelencina, in the district of Guadalaxara, discovered only a few years since, and worked on regular lodes in gneiss, and stated to have yielded enormous profits.

Lastly, near Ferrol in Galicia, and Zamora in Leon, tin ores occur in granite, and at the latter place are worked in several mines, not far distant from others, which produce argentiferous lead and antimony ores. The Carthaginians appear to have worked tin mines in this part of the Peninsula.

Within the Portuguese frontier very similar tin ores occur near the river Douro; and other localities in that kingdom are indicated as exhibiting ores of copper, antimony, and lead. Among the latter, the Palhal, and Carvalhal mines are working by an English (the 'Lusitanian') mining company.

Ores of iron occur at very numerous places in the Peninsula, but have hitherto been worked on a comparatively small scale. Those of Sommorostro near Bilbao, and of Marbella, are among the best known. The impulse given to iron-mining in Spain a few years ago has been checked by the present disturbed state of the country (1874).

Two ancient iron-works exist in Portuguese Estremadura, the one in the district of Thomar, and the other in that of Figueiro dos Vinhoss: they are supplied by mines of red oxide of iron, situated on the frontiers of this province and of Beira. One deposit of quicksilver ore occurs at Couna, in Portugal.

Mines of the North of Europe.

These mines are situated for the most part in the south of Norway, towards the middle of Sweden, and in the south of Finland, a little way from the shortest line drawn from the Lake Onega to the south-west angle of Norway. A few mines occur in the northern districts of Norway and Sweden. The main products of these several mines are iron, copper, and silver.

The iron mines of Norway lie on the coasts of the Gulf of Christiania, and on the side facing Jutland, principally at Arendal, at Krageroe, and the neighbourhood. The ores consist almost solely of black oxide of iron, which forms beds or veins of from 4 to 60 feet thick, incased in gneiss, which is accompanied with pyroxene (augite), epidote, garnets, &c. These iron ores are reduced in a great many smelting-furnaces situated on the same coast, and particularly in the county of Laurwig. Their annual product is about 16,500,000 lbs. avoird. of iron, in the form of cast iron, bar iron, sheet iron, nails, &c.; of which one-half is exported.

Norway possesses rich copper mines, some of which lie towards the south and the centre of the country; but the most considerable occur in the north, at *Quikkne*, *Læken*, *Selboe*, and *Rœraas*, near Drontheim. The mine of Rœraas, 16 miles from Drontheim, to the S.E. of the city, is opened on a very considerable mass of copper pyrites, and has been worked as an open-cast since 1664. It has poured into the market, from that time till 1701, 77,000,000 lbs. avoird. of copper. In 1805 its annual production was 864,600 lbs. Not far from the North Cape, copper mines have been for some years past actively worked by an English (the Alten) mining company, on irregular veins at Kaafiord and Raipas.

Norway comprehends also some celebrated silver mines. They are situated from 15 to 20 leagues S.W. of Christiania, in a mountainous country near the city of Kongsberg, which owes to them its population. Their discovery goes back to the year 1623, and their objects are veins of carbonate of lime, accompanied with asbestos and other substances in which native silver occurs, usually in small threads or network, and sometimes in considerable masses, along with sulphuret of silver. These veins are very numerous, and run through a considerable space, divided into four districts (arrondissements), each of which contains more than 15 distinct explorations. When a new mine is opened, it is generally as an open-cast, which embraces several veins, and they then prosecute by subterranean workings only those that appear to be of consequence. The workings are about 200 fathoms deep. Fire is employed for attacking the ore. In 1782 the formation of a new adit-level was commenced, destined to have a length of 10,000 yards, and to cost 60,000*l.* These mines, since their discovery till 1792, have afforded a quantity of silver equivalent to above 4,000,000*l.* sterling. The year 1768 was the most productive, having yielded 38,000 marcs of silver. Twice during the present century they have been threatened with abandonment, but have again become profitable, yielding from 1,300 to 1,400 kilograms of silver per annum.

Cobalt mines may be noticed at *Modum* or Fossum, 8 leagues W. of Christiania; they are extensive, but of little depth.

Lastly, graphite is explored at *Englidal*; and chromate of iron deposits have been noticed in some parts of Norway.

The irons of Sweden enjoy a merited reputation, and form one of the chief objects of the commerce of that kingdom. Few countries, indeed, combine so many valuable advantages for this species of manufacture. Inexhaustible deposits of iron ore are placed amid immense forests of birches and resinous trees, whose charcoal is probably the best for the reduction of iron. The different groups of iron mines and forges form small districts of wealth and animation in the midst of these desolate regions.

The province of Wermeland, including the north bank of the lake Wener, is one of the richest of Sweden in iron mines. The two most important are those of Nordmarck, 3 leagues north of Filipstadt, and those of Perseberg, 2½ leagues east from the same city. Filipstadt is about 50 leagues W. ¼ N.W. from Stockholm. Both mines are opened on veins or beds of magnetic oxide of iron several yards thick, directed from N. to S. in a ground composed of hornblende, talcose and granite rocks. These masses are nearly vertical, and are explored in the open air to a depth of 130 yards.

The principal iron mines of Rosslagen (part of the province of Upland), are those of Dannemora, situated 11 leagues from Upsal. They stand in the first rank of those of Sweden, and even of Europe. The masses worked upon are somewhat lenticular, and vertical, running from N.E. to S.W., and are incased in a ground formed of primary rocks, among which gneiss, petrosilex and granite are most conspicuous. They amount to three in number, very distinct, and parallel to each other; and are explored through a length of more than 1,500 yards, and to a depth of above 80, by the employment of fire, and blasting with gunpowder. The explorations are mere quarries, each presenting an open chasm 65 yards wide, by a much more considerable length and an appalling depth. Magnetic iron ore is extracted thence, which furnishes the best iron of Sweden and Europe; an iron admirably qualified for conversion into steel.

Of the works which prepare bar iron from the Dannemora ores, may be mentioned in the first class Löfsta, Osterby, Simö, and Ranäs.

The island of Utoe, situated near the coast of the province of Upland, presents also rich iron mines. The magnetic ore there forms a thick bed in the gneiss. It is worked in trenches far below the level of the sea. The ore cannot be smelted in the island itself; but is transported in great quantities to the continent.

The province of Smoland includes also very remarkable mines. Near Jönköping, a hill called the *Taberg* occurs, formed in a great measure of magnetic oxide of iron, contained in a greenstone in the midst of the gneiss.

In several parts of Lapland, the magnetic oxide of iron occurs in great beds or immense masses. At Gellivara, 200 leagues N. of Stockholm, towards the 67th degree of latitude, it constitutes a considerable mountain, into which an exploitation has been opened. The iron is despatched on small sledges drawn by rein-deer to streams which fall into the Lulea; and thence by water-carriage to the port of Lulea, where it is embarked for Stockholm.

There are a great many iron works in Dalecarlia, but a portion of the ores are got from alluvial deposits. Similar deposits exist also in the provinces of Wermeland and Smoland.

The annual production of the iron mines and furnaces of Sweden and Norway has increased but little of late years, the chief attention being devoted to the quality, and not to the quantity. At present it amounts to above 150,000 tons of pig iron, of which probably two-thirds are exported as bar iron, steel, &c.

The copper mines of Sweden are scarcely less celebrated than its iron mines. The principal is that of Falun or Kopparberg, situated in Dalecarlia, near the town of Falun, 40 leagues N.W. of Stockholm. It is excavated in an irregular and very powerful mass of pyrites, which in a great many points is almost entirely iron pyrites, but in others, particularly near the circumference, includes a greater or less portion of copper. This mass is enveloped in talcose or hornblende rocks. More to the west, there are three other masses almost contiguous to each other, which seem to bend in an arc of a circle around the principal mass. They are explored as well as the last. This was at first worked in the open air; but imprudent operations having caused the walls to crumble and fall in, since 1647 the excavation presents near the surface nothing but frightful precipices. The workings are now prosecuted by shafts and galleries into the lower part of the deposit, and have arrived at a depth of 194 fannars (nearly 430 yards). They display excavations spacious enough to admit the employment of horses, and the establishment of forges for repairing the miners' tools. It is asserted that the exploration of this mine goes back to a period anterior to the Christian era. During its greatest prosperity, it is said to have produced 11 millions of pounds avoird. of copper per annum, or about 5,000 tons. It furnishes now about the seventh part of that quantity; yielding at the same time about 70,000 lbs. of lead, with 50 marcs of silver, and 3 or 4 of gold. The ores smelted at Falun produce from 2 to 2½ of copper per cent. But the extraction of the metal is not the sole process; sulphur is also saved; and with it, or the pyrites itself, sulphuric acid and other chemical products are made. Round Falun, within the space of a league, 70 furnaces or factories of different kinds may be seen. The black copper obtained at Falun is converted into rose copper, in the refining hearths of the small town of *Ofwostad.*

In the copper mine of *Garpenberg*, situated 18 leagues from Falun, there occur 14 masses of ore quite vertical, and parallel to each other, and to the beds of mica-slate or talc-slate, amid which they stand. This mine has been worked for more than six hundred years.

The mine of *Nyakopparberg*, in Nericia, 20 leagues W. of Stockholm, presents masses of ores parallel to each other, the form and arrangement of which are very singular. It is worked by open quarrying, and with the aid of fire.

We may notice also the copper mines of Atvidaberg, in Ostrogothia, which furnish annually about a sixth part of the whole copper of Sweden.

There are several other copper mines in Sweden. Their whole number is ten; but it was formerly more considerable. They yield at the present day in all, about 2,000 tons of metallic copper.

The number of the silver mines of Sweden has in like manner diminished. In 1767, only 3 were reckoned under exploration, viz. that of *Hellefors*, in the province of Wermeland; that of *Segersfors*, in Nericia; and that of *Sala* or *Sahlberg*, in Westmannia, about 23 leagues N.W. of Stockholm. The last is the only one of any importance. It is very ancient, and passes for having been formerly very productive; though at present it yields only from 4 to 5,000 marcs of silver *per annum*. Lead very rich in silver is its principal product. It is explored to a depth of more than 200 yards. The soundness of the rock has allowed of vast excavations being made in it, and of even the galleries having great dimensions; so that in the interior of the workings there are winding machines, and carriages drawn by horses for the transport of the ores.

At Sala, there are deposits of sulphuret of antimony.

For the last 30 or 40 years, mines of cobalt have been opened in Sweden, principally at Tunaberg and Los, near Nyköping, and at Otward in Ostrogothia. The first are worked upon veins of little power, which become thicker and thinner successively; whence they have been called *bead-veins*. It appears that the products of these mines, though of good quality, are inconsiderable in quantity.

Lastly, there is a gold mine in Sweden; it is situated at Adelfors, in the parish of Alsfeda, and province of Smoland. It has been under exploration since 1737, on veins of auriferous iron pyrites, which traverse schistose rocks; presenting but a few inches of ore. It formerly yielded from 30 to 40 marcs of gold *per annum*, but for the last few years it has furnished only from 3 to 4.

The south of Finland and the bordering parts of Russia contain some mines, but they are far from having any such importance as those of Sweden.

At Orfjerwy near Helsingfors, a mine of copper occurs whose gangue is carbonate of lime, employed as a limestone.

Near Cerdopol, a town situated at the N.W. extremity of the Ladoga Lake, veins of copper pyrites were formerly mined.

Under the reign of Peter the Great, an auriferous vein was discovered in the granitic mountains which border the eastern bank of the Lake Ladoga, near Olonetz. It was rich only near the surface; and its working was soon abandoned.

Latterly, an attempt has been made to mine copper and iron ores near Eno, above and to the N.W. of Cerdopol, but with little success.

Some time ago, rich ores of iron, lying in veins, were worked near the Lake Shuyna, N.W. from Cerdopol; but this mine has also been relinquished.

The transition limestone which constitutes the body of Esthonia contains lead ore at *Arossaar* near *Fellin.* These ores were worked when these provinces belonged to the Swedes. It was attempted in 1806 to resume the exploitation, but without success.

Mines of the Ural Mountains.

This chain of mountains, which begins on the coasts of the icy sea, and terminates in the 50th degree of latitude amidst the steppes of the *Kirghiz*, after having formed, through an extent of more than 40 leagues, the natural limit between Europe and Asia, contains very rich and very remarkable deposits of metallic ores, which have given rise to important mines of iron, copper, and gold. These explorations are situated on the two slopes, but chiefly on the one that looks to Asia, from the environs of Ekaterinbourg to about 120 or 130 leagues north of that city. They constitute the department of the mines of Ekaterinbourg, one of the three belonging to Siberia.

The copper mines are pretty numerous, and lie almost wholly on the oriental slope of the chain. They are opened upon veins of a very peculiar nature, and which, although very powerful at the surface, do not extend to any considerable depth. These veins are in general filled with argillaceous matters, penetrated with red oxide of copper, and mingled with green and blue carbonates of copper, sulphuret of copper, and native copper. The most important workings are those of *Tourinsk* and *Nijni-Taguil.*

The first are situated 120 leagues north of Ekaterinbourg, towards the 60th degree of N. latitude, at the eastern base of the Uralian mountains, near the banks of the *Touria.* They amount to three, opened in the same vein, which turns round an angle presented by the chain in this place. The rock consists of a porphyry with a hornstone basis, of clay-slate, and of a white or greyish limestone, which form the roof and floor of the vein. The ore yields from 18 to 20 per cent., and these mines produced annually in 1786, 10,000 metric quintals (2,200,000 lbs. avoird.) of copper.

The mine of Nijni-Taguil is remarkable for the fine masses of malachite which it has produced.

At Bogoslowsk copper ores have also been largely worked from a contact-deposit between greenstone and limestone.

The beds of iron ore occur generally at a certain distance from the axis of the central chain. Those of the western slope lie sometimes in a grey compact limestone, which contains encrinites and other fossils, and appears to be much more modern than the rocks of the central chain. Both the one and the other seem to form large veins, which extend little in depth, or rather fill irregular and shallow cavities. The most common ore is the hydrous oxide of iron, hæmatite, or compact iron ore, sometimes mixed or accompanied with oxide of manganese, and occasionally with ores of zinc, copper, and lead. Black oxide of iron, possessing magnetic polarity, likewise frequently occurs, particularly in the mines of the eastern slope, on which, in fact, entire mountains of loadstone repose. All these ores, mixed with a greater or less quantity of clay differently coloured, are worked by open quarries, and most usually without using gunpowder. They yield rarely less than 50 or 60 per cent., and keep in action numerous smelting-houses situated on two flanks of the chain; the oldest of them have been established since 1628, but the greater number date only from the middle of the 18th century. The most celebrated mines are those of *Blagodat* and *Keskanar*, situated on the eastern slope from 30 to 50 leagues north of *Ekaterinbourg.* In the foundries of the eastern slope, anchors, guns, shot and shell, &c. are manufactured; and in the whole a considerable quantity of bar iron. The products of the works on the western side are directly embarked on the different feeders of the Volga, from which they are at no great distance. Those of the eastern slope are transported during winter on sledges to the same feeder streams, after crossing the least elevated passes of the Urals.

The quantity of materials manufactured by the iron works of both slopes, amounted annually, as far back as the year 1790, to more than 11,000,000 lbs. avoird. This country is peculiarly favoured by nature for this species of industry; for vast deposits of excellent iron ores occur surrounded by immense forests of firs, pines, and birches; woods, whose charcoal is excellently adapted to the manufacture of iron.

The copper mines of the Uralian mountains, and the greater part of the iron mines and foundries, form a portion of the properties of some individuals, who may be instanced as among the richest in Europe. The Russian Government has neglected no opportunity of promoting these enterprises. It has established at Tourinsk a considerable colony, and at Irbitz a fair, which has become celebrated.

There is only one gold mine in the Ural mountains, that of *Berezof*, situated three leagues N.E. of Ekaterinbourg, at the foot of the Urals, on the Asiatic side. It is famous for the chromate of lead, or red lead ore, discovered there in 1776, and worked in the following years, as also for some rare varieties of minerals. The ore of Berezof is a cavernous hydrate of iron, presenting here and there some small striated cubes of hepatic iron, and occasionally some pyrites. It contains five parts of gold in 100,000. This deposit appears to have a great analogy with the deposits of iron ore of the same region. It constitutes a large vein, running from N. to S., encased in a formation of gneiss, hornblende schists, and serpentine. It becomes poor in proportion to its distance from the surface. The exploitation, which is in the open air, has attained but a small depth, although carried on since the year 1726. The gold is extracted from the ore by stamping and washing. In 1786, 500 marcs were collected; but the preceding years had furnished only 200, because they then worked further from the surface. German miners were called in to direct the operations. Since that period, however, great attention has been bestowed on the education of the mining engineer officers, who now form a corps pre-eminent in attainments.

The auriferous sands, or 'stream' deposits of the Ural were discovered in 1814, and since 1823 have become very important. They extend over a district of some hundreds of miles in length, although with interruptions; the continuous portions of gold-bearing detritus, being generally from 50 to 600 yards in length and 10 to 60 in breadth. In some few places platinum has been similarly found. The form in which these precious metals occur, is generally in minute scales or grains, more rarely as lumps or *pepites*, which have, in the case of gold, attained in one instance the weight of 100 lbs., in that of platinum 23 lbs.

The Russian miners have observed that these deposits rarely overlie the granite or syenite; but generally the slaty rocks of the chain, near the outburst of serpentine or hornblendic rocks.

The beautiful plates of mica, well known in mineral cabinets, and even in commerce, under the name of *Muscovy talc*, or Russian mica, come from the Urals. There are explorations for them near the lake Tschebarkoul, on the eastern flank of this chain. From the same canton there is exported a very white clay, apparently a *kaolin*.

Twenty-five leagues north of Ekaterinbourg, near the town of Mourzinsk, there occur in a graphic granite, numerous veins, containing amethysts, several varieties of beryl, emeralds, topazes, &c.

It is difficult to obtain any reliable return of the production of minerals in Russia. The following Table of the production of the Russian mines during the years 1830, 1831, 1832, 1833, and 1834, by M. Teploff, one of their officers, exhibits very fairly the annual average production of the Russian mines even at the present time.

Substances	1830	1831	1832	1833	1834
	kil.	kil.	kil.	kil.	kil.
Gold . . .	6,260	6,582	6,916	6,706	6,626
Platinum . .	1,742	1,767	1,907	1,919	1,695
Auriferous silver	20,974	21,563	21,454	20,552	20,666
Copper . .	8,860,696	3,904,533	3,620,201	(3) 3,387,252	?
Lead . . .	698,478	792,935	688,351	716,500	?
Cast iron . .	182,721,274	180,043,730	162,480,224	(3) 159,118,372	?
Salt . . .	342,240,893	(2) 282,821,358	372,776,283	491,862,299	?
Coal . . .	7,863,642	9,774,998	6,596,034	8,227,528	?
Naphtha . .	4,253,000	4,253,000	4,253,000	4,253,000	?

MINES OF THE ALTAÏ MOUNTAINS.

At the western extremity of the chain of the Altaï mountains, which separate Siberia from Chinese Tartary, there exists a number of metalliferous veins, in which several important workings have been established since the year 1742. They constitute the locality of the mines of Kolywan; the richest in the precious metals of the three districts of this kind existing in Siberia.

These mines are opened up in the schistose formations which surround to the N. and W. and to the S.W. the western declivity of the high granitic chain, from which they are separated by formations consisting of other primary rocks. These schists alternate in some points with quartzose rocks, called by M. Renovantz hornstone, and with limestone. They are covered by a limestone, containing ammonites. The metalliferous region forms a semicircle, of which the first lofty mountains occupy the centre.

The most important exploration of this country is the silver mine of Zméof, or Zméinogorsk, in German *Schlangenberg*, situated to the N.W. of the high mountains in 51° 9′ 25″ N. L. and 79° 49′ 50″ long. east of Paris. It is opened on a great vein, which contains argentiferous native gold, auriferous native silver, sulphuret of silver, hornsilver, grey copper, sulphuret of copper, green and blue carbonated copper, red oxide of copper, copper pyrites, sulphuret of lead, and great masses of arsenic slightly argentiferous. There occur likewise sulphuret of zinc, or blende, iron pyrites, and sometimes arsenical pyrites. The gangues (vein-stones) of these different ores are sulphate of baryta, carbonate of lime, quartz, but rarely fluor-spar. The principal vein, which is of great power, has been traced through a length of several hundred fathoms, and to a depth of no less than 96 fathoms. In its upper portion, it has an inclination of about 50 degrees; but lower down it becomes nearly vertical. Its roof is always formed of clay-slate. On the foot-wall of the vein the slate alternates with hornstone. This vein pushes out branches in several directions; it is intersected by barren veins, and presents successive stages of different richness. The first years were the most productive.

The most important of the other silver mines of this department are those of Tcherepanofsk, 3 leagues S.E. of Zméof; those of Semenofsk, 10 leagues S.E.; those of Nicolaiefsk, 20 leagues to the SS.W.; and of Philipofsk, 90 leagues S.E. of the same place. The last mine lies on the extreme frontier of Chinese Tartary.

The mine of Zyrianofsk is opened amid talco-chloristic schists; and from workings about 180 yards in length yields about 800 tons of lead, 500 tons of copper, and 700 kilograms of silver per annum.

About 36,000 lbs. weight of silver, at the most, are furnished by the whole of the Altaï mines.

Since the year 1830 the gold workings of Siberia have attained a high degree of value; and, although the average proportion of gold is but 1 to 250,000 parts of refuse, a total quantity of 75,000 Russian lbs. of gold is given as the produce of the Siberian works in the best years. Those on the Yenisei and the Lena are the most productive.

The precious metals are not the sole product of this mineral district. There is an important copper mine 15 leagues W. of Zméof, in a chain of hills formed of granitic rocks, schists, porphyries, and shell-limestone, graduating into the plain. The vein presents copper pyrites, sulphide of copper, and native copper, disseminated in argillaceous substances, more or less ferruginous, and of different degrees of hardness. This mine, which bears the name of Loktiefsk, furnished annually, at the date of 1782, 330,000 lbs. avoirdupois of copper. At present, it and the neighbouring mine of Solotoushinsk yield little more than 120,000 lbs. per annum each. At Tchakirskoy, on the banks of the Tscharisch, towards the northern extremity of the metalliferous semicircle mentioned above, there is a mine of argentiferons copper and lead, opened in a very large but extremely short vein. Besides the lead and copper ores, including a little silver, this mine affords a great quantity of calamine (carbonate of zinc), which affords occasionally fine stalactites of a white or green colour.

The northern flank of the Altaï mountains presents few mines. Some veins of copper exist 200 leagues E. of Zméof, near the spot where the river Yenisei issues from the Saïansk mountains, which are a prolongation of the Altaïan chain.

The Altaï produces but little lead; but the Crown works, in this and the Nertschinsk district, together produce about 1,680,000 lbs. annually.

The first smelting-house erected in this district was in the middle of the metalliferous region at *Kolywan*, the place from which it takes its name. It has been suppressed on account of the dearth of wood in the neighbourhood of the mines. The principal existing foundry is that of Barnaoul on the Obi, 50 leagues N. of Zméof. Plumbago has been largely worked by M. Alibert at Irkutsk, near Lake Baikal.

Mines of Daouria.

The name Daouria is given to a great region, wholly mountainous, which extends from the Baikal Lake to the Eastern Ocean. Its chief mining district is beyond the Jablonnoï chain, which divides the waters of the Saghalien or Amour from the streams which flow to the icy sea. The mines opened here constitute the third arrondissement of the Siberian mines, called that of Nertschinsk, from the name of its capital, which lies more than 1,800 leagues E. of St. Petersburg.

The country of the metalliferous portion of Daouria is formed of granite, hornschiefer, and schists, on which reposes a grey limestone, sometimes siliceous and argillaceous, rarely fossiliferous, and in which the repositories of lead occur. The plains of these regions, often salt-deserts, exhibit remarkable sandstones and puddingstones; as also vesicular rocks of a volcanic aspect. It appears that the metalliferous limestone is much dislocated, and the lead-veins are subject to several irregularities, which render their exploitation difficult and uncertain. The mines lie chiefly near the banks of the Schilca and the Argoun, in several cantons, at a considerable distance from one another; wherefore it was requisite to build a great number of smelting-furnaces. The want of wood has placed difficulties in the working of some of them. The ores are principally oxides and carbonates of lead, with brown oxide of iron, calamine, and a varying proportion of native silver, occurring seldom in regular bodies, but generally in cavernous openings, more or less united by narrow veins.

The silver extracted from the mines of Daouria, contains a very small proportion of gold. M. Patrin says that their annual product was, towards the year 1784, from 30,000 to 35,000 marcs of silver. Since that time it has diminished. The exploitation of some of the mines of Daouria goes back to the end of the 17th century. It had been commenced in some points by the Chinese, who were not entirely expelled from this territory till the beginning of the following century. Many of the mines are reputed to be exhausted: among the best of the now existing works are those of Akatouiefsk, Algatchinsk, and Ivanofsk.

Besides the lead mines, there are some unimportant mines of copper in Daouria, and in different explorations of this region, arsenical pyrites, from which arsenious acid is sublimed in factories established at Jutlack and at Tchalbutchinsky.

About 45 leagues to the S. of Nertschinsk the mountain of Odon-Tchelon occurs, celebrated for the different gems or precious stones extracted from it. It is formed of a friable granite, including harder nodules or balls which inclose topazes: it is very analogous to the topaz-rock of Saxony. In this granite there are veins containing cavities filled with a ferruginous clay, in which are found emeralds, aqua-marines, topazes, crystals of smoked quartz, &c. Multitudes of these minerals have been extracted by means of some very irregular workings. The mountain of Toutt-Kaltoui, situated near the preceding, offers analogous deposits. The presence of wolfram had excited hopes that tin might be found in these mountains; hopes which have been realised by its discovery on the Onone. There are some unworked deposits of sulphide of antimony in this country.

Considerable attention has of late years been directed to the tributaries of the Amour river, many of which have yielded large quantities of gold, and some districts on the northern borders of the sea of Okotsk, are reported as being rich in ores of silver.

Mines of Hungary.

It must be premised of this country, that many of the metalliferous formations which used some years ago to be considered of high geological antiquity, have been proved to belong to the secondary, and even to the tertiary period; whence it is only as a matter of convenience rendered the more needful by a number of undetermined questions, that all the mines are here classed together.

The metallic mines of this kingdom, including those of Transylvania, and the Bannat of Temeschwar, form four principal groups, which we shall denote by the group of the N.W., group of the N.E., group of the E., and group of the S.E.

The group of the North-West embraces the districts of Schemnitz, Kremnitz, Kœnigsberg, Neusohl, and the environs of Schmœlnitz, Bethler, Rosenau, &c.

Schemnitz, a royal free city of mines, and the principal centre of the mines of Hungary, lies 25 leagues to the N. of Buda, 560 yards above the sea, in the midst of a small group of mountains covered with forests. The most part of these mountains, the highest of which reaches an elevation of 1,130 yards above the ocean, are formed of barren trachytes (rough trap-rocks); but, within their ambit, a formation is observed, consisting of greenstone porphyries, connected with syenites, passing into granite and gneiss, and including subordinate beds of mica-slate and limestone. It is in this formation that all the mines occur.

It has been long known that the greenstone porphyries of Schemnitz have intimate relations with the metalliferous porphyries of South America. M. Beudant, on comparing them with those brought by Von Humboldt from Guanaxuato, Real del Monte, &c., has recognised an identity in the minutest details of colour, structure, composition, respective situation of the different varieties, and even in the empirical character of effervescence with acids.

The metalliferous rocks of Schemnitz appear in a tract of a few miles in extent, and are traversed by a principal group of five master-lodes coursing N.E. and S.W., besides a great number of less important veins, which occur on the north side of the ridge of the Paradise mountain. The most powerful of the first of these, the *Spitaler Gang*, attains occasionally a width of from 10 to 20 fathoms; and is traceable for upwards of 4 miles in length. The lodes seldom exhibit distinct walls, but a portion of the greenstone porphyry (*saxum metalliferum* of the older miners) is often decomposed, and impregnated with iron pyrites for some distance from the plane of contact. Intersections and dislocations are of rare occurrence.

The substances which constitute the body of these veins, are fragments of the adjoining rock, often decomposed to clay, drusy quartz, ferriferous carbonate of lime and sulphate of baryta, with which occur sulphuret of silver mixed with native silver containing more or less gold, which is rarely in visible scales; ruby-silver ore, argentiferous galena, blende, copper, and iron pyrites, &c. The sulphuret of silver and the galena are the most important ores. Sometimes these two substances are isolated, sometimes they are mixed in different ratios, so as to furnish ores of every degree of richness, from such as yield 60 per cent. of silver down to the poorest galena. The gold seldom occurs alone; it generally accompanies the silver in variable proportion, which has undoubtedly diminished in depth. The galena appears to occur in comparatively larger quantity in the greatest depths attained.

The ores of Schemnitz are all treated by fusion; the poor galenas at the smelting work near Schemnitz (Bleihütte), and the resulting lead is sent as *work lead* to the smelting-houses of Kremnitz, Neusohl, and Scharnowitz, whither all the silver ores prepared in the different spots of the country are transported in order to be smelted.

The mines of Schemnitz, opened 800 years ago, have been worked to a depth of more than 200 fathoms. The explorations are in general well conducted. Excellent galleries of efflux have been excavated; the waters for driving the machinery are collected and applied with skill. It may be remarked, however, that these mines have declined from the state of prosperity in which they stood a century ago. Maria Theresa, established in 1760, at Schemnitz, a school of mines. This acquired at its origin, throughout Europe, a great celebrity, but will probably not recover from the blow which it received in the civil war of 1848–9. After numbering before those events 300 or 400 students, it has seen a great proportion of them pass to the rival schools of Gratz and Przibram.

Kremnitz lies about five leagues N.N.W. of Schemnitz, in a valley flanked on the right by a range of hills formed of rocks quite analogous to the metalliferous rocks of Schemnitz. In the midst of these rocks, veins are worked nearly similar to those of Schemnitz; but the quartz which forms their principal mass is more abundant, and contains more native gold. Here is also found comparatively a great abundance of sulphide of antimony. The metalliferous district is of very moderate extent, and is surrounded by the trachytic formation which geologically overlies it, forming to the east and west considerable mountains.

The city of Kremnitz is one of the most ancient free royal cities of mines in Hungary. It is said that mines were worked there even in the times of the Romans; but it is the Germans who, since the middle ages, have given a great development to these exploitations. There exists at Kremnitz a Mint-office, to which all the gold and silver of the mines of Hungary are carried in order to be parted, and where all the chemical processes, such as the fabrication of acids, &c., are carried on in the large way.

About six leagues NN.E. from Schemnitz, on the banks of the Gran, lies the town of Neusohl, founded by a colony of Saxon miners. The mountains surrounding it include mines very different from those of which we have been treating. At Herrengrund, two leagues from Neusohl, greywacke forms pretty lofty mountains; this rock is covered by transition limestone, and is supported by mica-slate. The lower beds contain bands of copper ores, chiefly copper pyrites. The mica-slate includes likewise masses of ore, apparently constituting veins in it. These ores have been worked since the thirteenth century. The copper ore is argentiferous, and these mines produce annually about 2,137 cwts. of copper and 1,345 marcs of silver.

In the higher ridge which adjoins this range, and worked in a region of snows and bears, is the interesting mine of Magurka, on an E. and W. lode in granite, yielding gold, antimony, and a little galena.

The mines of Lower Hungary (Nieder-Ungarn), employ 15,500 workmen, and yield metals of the annual value of 360,000*l.*

Eighteen or twenty leagues to the east of Neusohl, we meet with a country very rich in iron and copper mines, situated chiefly in the neighbourhood of Bethler, Schmœlnitz, Einsiedel, Roseneau, &c. Talcose and clay-slates form the principal body of the mountains here, along with hornblende rocks. The veins appear to lie generally conformably to the strata. The ores of iron are sparry ore, and especially hydrous oxide of iron, compact and in concretions, accompanied with specular iron ore. They give employment to many large smelting-houses, mostly in the counties of Gömor and Zips. The copper mines lie chiefly in the neighbourhood of Schmœlnitz and Gœlnitz. The copper extracted contains about 6 or 7 ounces of silver in the hundredweight, and the *fahlerz* has been proved to contain a considerable percentage of mercury, which is now extracted. This group of mines, belonging almost entirely to private persons, and chiefly worked by a company called the *Waldbürgerschaft*, produces annually 17,000 cwts. of copper, 4,650 marcs of silver, and 7,967 lbs. of quicksilver. In the neighbourhood of Dobschau, large quantities of the ores of cobalt and nickel are obtained.

To conclude our enumeration of the mineral wealth of this country, it remains merely to state that there are *opal* mines in the environs of Czervenitza, situate in the trachytic conglomerate, which in several localities contains *opalised* wood.

Group of the North-East, or of Nagybanya.—The mines of this group lie in a somewhat considerable chain of mountains, which, proceeding from the frontiers of Buckowina, where it is united to the Carpathians, finally disappears amidst the saliferous sandstones between the *Theiss*, *Lapos*, and *Nagy Szamos*, on the northern frontiers of Transylvania. These mountains are partly composed of rocks analogous to those of Schemnitz, traversed by veins which have much resemblance to the veins of this celebrated spot. Into these veins a great many mines have been opened, the most important of which are those of Nagybanya, Kapnik, Felsobanya, Veresviz, Miszbanya, and Laposbanya. All these mines produce gold. Those of Laposbanya furnish, likewise, argentiferous galena, and those of Kapnik copper, especially as silver-fahlerz. Realgar occurs in the mines of Felsobanya; and orpiment in those of Ohlalapos. Several of them produce manganese and sulphuret of antimony. Lastly, towards the north, in the county of Marmarosh, lies the important copper mine of *Borscha*, and near the frontiers of Buckowina the lead mine of *Rodnau*, in which also much zinc ore occurs.

The mines composing the group of the East, or of Abrudbanya, occur almost all in the mountains which rise in the western part of Transylvania, between the *Lapos* and *Maros*, in the environs of *Abrudbanya*. There may be noticed in this region, limestones, sandstones, trachytes, basalts, and porphyries, very analogous to the greenstone porphyries of Schemnitz. It seems to be principally in the latter rocks that the mines forming the wealth of this country occurs, but some of them exist also in the mica-slate, the greywacke, and even in the limestone. The principal veins are at Nagyag, Körösbanya, Offenbanya, Vöröspatak, Boitza, Csertesch, Fatzbay, Füzes, Vulkoj, Porkura, Butschum, and Toplitza. There are very numerous mines, the whole of which produce auriferous ores smelted at the works of Zalathna. These mines contain also silver, copper, antimony, and manganese. They are celebrated for their *tellurium* ores, which were peculiar to them prior to the discovery of this metal a few years back in Norway. The auriferous deposits contained in the greenstone porphyry are often very irregular. The mines of Nagyag are the richest and best worked. The numerous veins of the district occur partly in the porphyry, and partly in a sandstone which used to be termed greywacke, and considered a transition rock, but is now ascribed to the upper secondary period. The gold is accompanied by galena, realgar, ores of manganese, iron, zinc, and rarely of silver.

At Rezbanya ores of copper and lead are worked in small veins, which intersect crystalline schists and marble.

Large deposits of iron ore are worked near Vayda Hunyad, and south-west of Rezbanya on the borders of porphyry and limestone.

The group of the South-East, or of the Bannat of Temeschwar, occurs in the mountains which block up the valley of the Danube at Orschova, through a narrow gorge of which the river escapes. The principal mines are at Oravitza, Moldawa, Szaszka, and Dognaczka. They produce chiefly argentiferous copper, yielding a marc of silver (nearly ½ lb.) in the hundredweight, with occasionally a little gold. Ores of lead, zinc, and iron, are also met with. The mines are famous for their beautiful specimens of blue carbonate of copper, and various other minerals. The mine of Moldawa affords likewise orpiment. These metallic deposits lie in flats and veins; the former occurring particularly between the mica-slate and the limestone, or sometimes between the limestone and the syenite porphyry. Well-defined veins also are known to exist in the syenite and the mica-slate. The Bannat possesses, moreover, important iron mines at Moravitza and Ruskberg. Cobalt ores occur likewise in these regions. The mines of the Bannat have been leased, together with the railroads, to a French company.

The mines constituting the four groups now described are not the sole metallic mines possessed by Hungary. A few others, but generally of little importance, are scattered over different parts of this kingdom. Several have been noticed in the portion of the Carpathians which separates Transylvania from Moldavia and Wallachia. Their principal object is the exploration of some singular deposits of galena.

Besides the mines just noticed, Hungary contains some coal and lignite mines, numerous mines of rock-salt, and several deposits of golden sands situated chiefly on the banks of the Danube, the Marosch, and the Nera.

Mines of South America.

Few regions are so celebrated for their mineral wealth as the great chain which, under the name of the Cordillera of the Andes, skirts the shores of the Pacific Ocean from the land of the Patagonians to near the north-west point of the American Continent. Who has not heard of the mines of Mexico and Potosi? The mineral wealth of Peru has passed into a proverb. More recently the gold of California has thrown half the world into a fever of excitement.

The most important mines of the Cordilleras have been those of silver; but several of gold, mercury, copper, and lead, have likewise been opened. These mountains are not equally metalliferous in their whole extent. The workings occur in a small number of districts, far distant from each other.

In the Andes of Chili, particularly in the district of Copiapo, silver mines are explored, which afford chiefly ores of an earthy or ferruginous nature, mingled with small particles of ore with a silver base, known there under the name of *pacos*. Sulphide, chloride, and chloro-bromide of silver are also found, and an alloy of silver and mercury called *arquerite*. The same province presents also copper mines of considerable importance, especially in Coquimbo and Huasco, from which are extracted native copper, red oxide, carbonate of copper (malachite), and copper pyrites, associated with some chloride of copper. In a few mines, masses of native copper of extraordinary magnitude have been found.

The second metalliferous region of the Andes occurs between the 21st and 15th degrees of south latitude. It includes the celebrated mountains of Potosi, situated in nearly the 20th degree of south latitude, on the eastern slope of the chain, and several other districts likewise very rich, which extend principally towards the north-west, as far as the banks of the lake Titicaca, and even beyond it, through a total length of nearly 150 leagues. All these districts, which formerly depended on Peru, were united in 1778, to the government of Buenos Ayres, and are now included in Bolivia. The mines of Potosi were discovered in 1545, and have furnished since that period till our days, a body of silver which Von Humboldt values at 230,000,000*l* sterling. The first years were the most productive. At that time ores were often found which afforded from 40 to 45 per cent. of silver. Since the beginning of the eighteenth century, the average richness of the ores does not exceed above from 3 to 4 parts in 10,000. These ores are therefore very poor at the present day; they have diminished in richness in proportion as the excavations have become deeper. But the total product of the mines has not diminished in the same proportion; abundance of ore having made up for its poverty. Hence, if the mountain of Potosi is not, as formerly, the richest deposit of ore in the world, it may, however, be still placed immediately after the famous vein of Guanaxuato. The present yield is estimated at about 50,000 lbs. troy. The ore lies in veins in a primary clay-slate, which composes the principal mass of the mountain, and is covered by a bed of clay-porphyry. This rock crowns the summit, giving it the form of a basaltic hill. The veins are very numerous; several, near their outcrop, were almost wholly composed of sulphuret of silver, antimoniated sulphuret of silver, and native silver. In 1790, seven copper mines were known in the vice-royalty of Buenos Ayres, seven of lead, and two of tin; the last being merely washings of sands found near the river Oraro.

On the opposite flank of the chain, in a low, desert plain, entirely destitute of water, which adjoins the harbour of Iquique, and forms a part of Peru, occur the silver mines of Huantajaya, celebrated for the immense masses of native silver which have been sometimes found in them. In 1758 one was discovered weighing eight cwts.

Baron Humboldt quotes 40 cantons of Peru as being at the time of his journey most famous for their subterranean explorations of silver and gold. Those of gold are found in the provinces of Huaailas and Pataz; the silver is chiefly furnished by the districts of Huantajaya, Pasco, and Chota, which far surpass the others in the abundance of their ores.

The silver mines of the district of Pasco are situated about 30 or 40 leagues north of Lima, in 10½ degrees of south latitude, 4,400 yards above the sea-level, on the eastern slope of the Cordilleras, and near the sources of the river Amazon. They were discovered in 1630. These mines, and especially those of the Cero of Yauricocha, are actually the richest in all Peru. Their annual produce is above 400,000*l*. The ore is an earthy mass of a red colour, containing much iron, mingled with particles of native silver, hornsilver, &c., constituting what they call *pacos*. At first nothing but these *pacos* were collected; and much grey copper and antimoniated sulphuret of silver were thrown amongst the rubbish. The mean produce of all the ores is $\frac{1}{1250}$;

or an ounce and $\frac{28}{100}$ per cwt.; although some occur which yield 30 or 40 per cent These rich deposits do not seem to be extended to a great depth; they have not been pursued farther than 130 yards, and in the greater part of the workings only to from 85 to 45. Forty years ago, these mines, which produced nearly 2,000,000 of piastres annually, were the worst worked in all South America. The soil seems as if riddled with an immense number of pits, placed without any order. The drainage of the waters was effected by the manual labour of men, and was extremely expensive. In 1816, some Europeans, among whom were several miners from Cornwall, erected, under the direction of the celebrated Richard Trevithick, several high-pressure steam-engines, imported from England, and introduced a considerable improvement in the workings.

The total yield of Peru is estimated at about 300,000 lbs. troy per annum.

The mines of the province of Chota are situated in about seven degrees of south latitude. The principal ores are those of Gualcayoc, near Mecuicampa, discovered in 1771; their outcrop occurs at the height of 4,500 yards above the sea; the city of Mecuicampa itself has 4,000 yards of elevation, that is, higher than the highest summits of the Pyrenees. The climate is hence very cold and uncomfortable. The ore is a mixture of sulphuret of silver and antimoniated sulphuret, with native silver. It constitutes veins of which the upper portion is formed of *pacos*, and they sometimes traverse a limestone and sometimes a hornstone, which occurs in subordinate beds. The annual produce of the mines is 67,000 marcs of silver, according to Von Humboldt.

In the districts of Huaailas and Pataz, which are at a little distance from the former two, gold mines are worked. This metal is extracted chiefly from the veins of quartz, which run across the primary schistose mountains. The district of Huaailas contains also lead mines. Peru possesses, moreover, some mines of copper.

The quicksilver mine of Huancavelica, long the only important mine of this species which was worked in the New World, occurs on the eastern flank of the Andes of Peru, in 13 degrees of south latitude, at upwards of 6,000 yards above the level of the sea. It does not seem referrible to the same class of deposits with the mines hitherto mentioned, but occurs in sandstones and shales, apparently of the carboniferous period. Indications of mercurial ores have been observed in several other points of the Andes of Northern Peru, and the south of New Granada.

Deposits of rock salt are known to exist in Peru, especially near the silver mines of Huantajaya; and nitrate of soda is found in large quantity in the desert of Tarapaca.

On receding from the district of Chota, the Cordilleras are less abundantly stored with metallic wealth, to the isthmus of Panama, and even far beyond it. The kingdom of New Granada offers but a very small number of silver mines. There are some auriferous veins in the province of Antioquia, and in the mountains of Guamoco. The province of Caracas, the mountains of which may be considered as a ramification of the Cordilleras, presents at Aroa a copper mine which furnishes annually from 700 to 800 metric quintals (1,400 to 1,600 cwts.) of this metal. Finally, we may state in passing, that there is a very abundant salt mine at Zipaquira, in the province of Santa-Fé, and that between this point and the province of Santa-Fé-de-Bogotà, a coal-field occurs at the extraordinary height of 2,700 yards. Emeralds are worked at Muzo.

Although Mexico presents a great variety of localities of ores, almost the only ones worked are those of silver. Nearly the whole of these mines are situated on the back or the flanks of the Cordilleras, especially to the west of the chain, at the height of the great table-land which traverses this region of the globe, or a little below its level in the chains which divide it. They lie in general between 2,000 and 3,000 yards above the sea; a very considerable elevation, which is favourable to their prosperity, because in this latitude there exists at that height a mean temperature mild, salubrious, and most propitious to agriculture. There were at the time of Humboldt's visit, from 4,000 to 5,000 deposits of ore exploited. The workings constituted 3,000 distinct mines, which were distributed round 500 head-quarters or *Reales*. These mines are not, however, uniformly spread over the whole extent of the Cordilleras. They may be considered as forming eight groups, which altogether do not include a greater space than 12,000 square leagues; viz. hardly more than the tenth part of the surface of Mexico.

These eight groups are, in proceeding from south to north,—

1. The group of *Oaxuaca*, situated in the province of this name at the southern extremity of Mexico properly so called, towards the 17th degree of north latitude. Besides silver mines, it contains the only veins of gold explored in Mexico. These veins traverse gneiss and mica-slate.

2. The group of *Tasco*. The most part of the mines which compose it are situated 20 or 25 leagues to the south-west of Mexico, towards the western slope of the great *plateau*.

3. The group of *Biscania*, about 20 leagues north-east of Mexico. It is of moderate

extent, but it comprehends the rich workings of Pachuca, Real del Monte, and Moram. The district of Real del Monte contains only a single principal vein, named *Veta Bezicana* of Real del Monte, in which there are several workings; it is, however, reckoned among the richest of Mexico.

4. The group of *Zimapan*. It is very near the preceding, about 40 leagues north of Mexico, towards the eastern slope of the plateau. Besides numerous silver mines, it includes abundant deposits of lead, and some mines of yellow sulphuret of arsenic.

5. The *Central group*, of which the principal point is *Guanaxuato*, a city of 70,000 inhabitants, placed at its southern extremity, and 60 leagues NN.W. of Mexico. It comprises among others the famous mine districts of *Guanaxuato, Catorce, Zacatecas,* and *Sombrerete*; the richest in Mexico, which alone furnish more than half of all the silver which this kingdom brings into circulation.

The district of Guanaxuato presents only one main vein, called the *Veta Madre*. This vein is enclosed principally in clay-slate, to whose beds it runs parallel, but occasionally it issues out of them to intersect more modern rocks. The vein is composed of quartz, carbonate of lime, fragments of clay-slate, &c.; and includes the sulphurets of iron, of lead, and of zinc in great quantities, some native silver, sulphide of silver, and red silver; its power (thickness of the vein) is from 43 to 48 yards. It is recognised and worked throughout a length of upwards of three leagues, though the principal workings are within 2,000 yards; and contains 19 exploitations, which produced annually nearly 1,200,000*l*. in silver. One of the explorations, that of Valenciana, produces 320,000*l*.; being equal to about one-fifteenth of the total product of the 3,000 mines of Mexico. Since 1764, the period of its discovery, its nett annual product has never been less than from two to three millions of francs (80,000*l*. to 120,000*l*.); and its proprietors, at first men of little fortune, became, in ten years, the richest individuals in Mexico, and perhaps in the whole globe.

The workings of this mine are very extensive, and penetrate to a depth of 2,000 feet.

The district of Zacatecas presents in like manner only a single vein in greywacke; which, however, is the seat of several workings.

The deposits mined at Catorce are in limestone; the mine called *Purissima de Catorce* has been explored to about 650 yards in depth; and yielded in 1796 nearly 220,000*l*. There are also mines of antimony in the district of Catorce.

Since the year 1824, several English companies, on a large scale, have undertaken the working of some of the Mexican silver mines. Of late years many of them have been fairly successful.

Towards the western part of the group of which we are now speaking, copper mines are worked in the provinces of Valladolid and Guadalaxara; the ores being chiefly composed of suboxide of copper (ruby copper), sulphide of copper, and native copper. These mines produce about 2,000 metric quintals of copper annually (440,000 lbs. English). In the same district, ores of tin are collected in the alluvial soils, particularly near Mount Gigante. The concretionary oxide of tin, so rare in Europe, is here the most common variety. This metal occurs also in veins.

The central part of Mexico contains many indications of sulphide of mercury (cinnabar); but in 1804 it was worked only in two places, and to an inconsiderable extent.

6. The group of *Neu Gallicia* is situated in the province of this name, about 100 leagues N.W. from Mexico. It comprises the mines of Bolanos, one of the richest districts.

7. The group of *Durango* and *Soaora*, in the intendancies of the same name. It is very extensive. The mines are situated in part on the table-land, and in part on the western slope. Durango is 140 leagues NN.W. of Mexico. Tin ore is found here.

8. The group of *Chihuahua*. It takes its name from the town of Chihuahua, situated 100 leagues N. of Durango. It is exceedingly extensive, but of little value; and terminates at 29° 10′ of north latitude.

Mexico possesses, besides, several mines which are not included in the eight preceding groups. Thus the provinces of New Leon and of New Santander present abundant ores of lead. New Mexico contains copper mines and many others.

Lastly, rock-salt is mined in several points of New Spain; and coal seems to occur in New Mexico.

The richness of the different districts of the *silver mines* or *reales* is extremely unequal. Nineteen-twentieths of these *reales* do not furnish altogether more than one-twelfth of the total product. This inequality is owing to the excessive richness of some deposits. The ores of Mexico are principally in veins; beds and masses are rare. The veins traverse chiefly, and perhaps only, igneous and transition rocks, among which certain porphyries are remarked as very rich in deposits of gold and silver. The silver ores are mostly sulphide of silver, black antimoniated sulphide of silver (stephanite and polybasite), muriate of silver (horn silver), and grey copper. Many explorations are carried on in certain earthy ores, called *colorados*, similar to the *pacos* of Peru. Lastly, there are ores of other metals, which are worked principally, and sometimes exclusively, for the silver which they contain; such are the argentiferous sulphides of lead, of copper, and of iron.

Ores of very great richness occur in Mexico; but the average is only from 3 to 4 ounces per cwt., or from 18 to 25 in 10,000. There are some, indeed, whose estimate does not exceed $2\frac{1}{5}$ ounces. Almost all the argentiferous veins afford a little gold; the silver of Guanaxuato, for example, contains $\frac{1}{360}$. The enormous product of the Mexican mines is to be ascribed rather to the great facility of working them, and the abundance of ores, than to their intrinsic richness. The present yield is estimated at above 5,000,000*l.* for silver, and 62,000*l.* for gold.

The art of mining was little advanced in this country at the period of Humboldt's journey; the workings presented a combination of small mines, each of which had only one aperture above, without any lateral communications between the different shafts.

The form of these explorations was too irregular to admit of their being called *regular stopes.* The shafts and the galleries were much too wide. The interior transport of the ores is generally effected on the backs of men; rarely by mules. The machines for raising the ore and drawing the water are in general ill-combined, and the horse-whims for setting them in motion ill-constructed. The timbering of the shafts is very imperfectly executed; the walled portions alone are well done. There are some adit-levels, but they are too few, and ill directed. The efforts of the English companies have produced but little change either in the mining or subsequent treatment of the ores.

The silver ores of Spanish America are treated partly by fusion and partly by amalgamation, but more frequently by the latter mode; hence the importation of mercury forms there an object of the highest importance, especially since the quicksilver mine of *Huancavelica* fell in, and ceased to be worked on the same scale as previously.

Gold mining is carried on in Nicaragua, and some gold is also yielded by Costa Rica, and the Island of Aruba.

The most important of these gold-sands are washed on the western slope of the Cordilleras, viz.: in New Granada, from the province of Barbacoas to the Isthmus of Panama, and to Chili. There are likewise some on the eastern slope of the Cordilleras, in the high valley of the river Amazons. The washings of New Granada produce, also, some platinum.

The mines, properly so called, and the washings of South America, furnish, altogether, 42,575 marcs, or 10,418 kilogrammes (22,920 lbs. Eng.) of gold, worth 1,435,720*l.*

Besides the extensive washings of the sands that produce the diamonds and other precious stones, the platinum, and a great part of the gold of Brazil, mines of gold, lead, and iron are opened in what appear to be ancient geological formations, very different from those of the Cordilleras. There are no silver mines, and this, again, indicates a great difference between the deposits of Brazil and those of Spanish America. The province of Minas-Geraes in Brazil is that most remarkable for its mineral productions. The slaty strata of the country contain intercalated portions of quartzose rock, among which a micaceous one, called *Itacolumite*, and one largely charged with scales of specular iron, termed *Jacotinga*, are regarded as constant accompaniments of the gold.

Several English companies have for years worked gold mines in this region; among which that of St. John d'El Rey still yields a considerable profit, due in a great measure to the steady skill and economy with which the underground works, as well as the stamping and dressing of the auriferous 'stone' is conducted: this is an auriferous pyrites. Among the most noted of the mines are the Bahu, Gongo Soco, and Morro Velho, which although yielding only from two to three oitavas (or eighths of an ounce) per ton, are worked on a large scale. The Morro Velho, which was the largest gold mine in Brazil, is now suffering from the effects of a most disastrous fire which occurred there a few years ago. Among other interesting minerals, the rare metal palladium is found mingled with some of the Brazilian gold, and it was owing to the liberality of the well-known assayer, Percival Johnson, F.R.S., that the Geological Society of London was for years enabled to bestow an annual 'Wollaston' medal struck in palladium, of which that chemist was the discoverer.

MINES OF NORTH AMERICA.

Within the last few years a stupendous activity in the production of certain metals has succeeded to the unimportant trials which at intervals used to be made. It was especially the discovery of gold in California in 1848, which invited the attention of the world to the metallic riches of the Pacific side of this continent, or to the western flank of the continuation of the great chain of mountains which we have traced upwards from South America.

Almost the entire quantity of the gold produced in California is obtained from stream-works, washings, or 'diggings,' but the precious metal itself has evidently been derived from veins in the granitic and the ancient slaty rocks which constitute the range of the Sierra Nevada. The alluvial deposits occupying ancient river-courses are termed 'deep placers,' whilst those which have been re-distributed, and lie near the surface, are called 'shallow placers.' The gold-bearing gravels are usually worked by a process known as 'hydraulic mining.' See GOLD. Platinum and osmiridium have also been found here.

The auriferous tracts extend northward far into the British territory, and are worked in British Columbia.

In one of the side valleys of San José, a mine of quicksilver, 'New Almaden,' has for some years been opened upon irregular and contorted deposits of cinnabar, associated with clay-slates highly inclined and similarly contorted. It is said that above 10,000 cwts. of mercury are produced here annually.

On the eastern or Atlantic side of the North American continent, the existence of gold has long been known, as well in alluvium in Virginia, Carolina, Georgia, and Canada, as in veins which occur at intervals in the schist rocks of the Appalachian chain, and which have given rise to numerous explorations.

The veins appear generally to course NN.E. and SS.W., and to consist mainly of quartz, often extending to a great thickness. Few, however, of these mines have been followed down to a depth of more than 100 feet, or have been developed on a continuously large scale.

Lead mines have been worked in distinct veins at Rossie, St. Lawrence County, N.Y., at Shelburne in New Hampshire, Southampton and Northampton, in Massachusetts, Middleton, Connecticut, Chester County, and Wheatley mines, Pennsylvania; but the most important are those opened in irregular deposits sometimes vertical, at others horizontal, which distinguish the Silurian limestones of the Upper Mississippi. The lead-bearing region is 87 miles long from east to west, and 54 miles broad from north to south, the chief centres being Galena, Mineral Point, and Dubuque. The ore, generally pure galena, occurs with great irregularity. It occupies only one zone, about 100 feet in thickness, of the 'galena' limestone, and hence the mines have been but shallow. In Missouri an analogous state of things occurs. Copper has been worked at several mines in the Atlantic States, in Maryland; in New Jersey; several localities in Tennessee; and Perkiomen in Pennsylvania, where the veins occur in new red sandstone and shale.

In 1841 Mr. Doughton, state geologist for Michigan, first drew public attention to the native copper of Lake Superior, which has been the object of very numerous workings, and has been produced in steadily increasing quantity.

The copper occurs in a district of bedded augitic trap, amygdaloid, and sandstone, with conglomerate of the lower Silurian period, and the rocks are especially remarkable for bearing native copper with but little of the ordinary ores of that metal.

Ores of zinc are associated with lead ores at several of the above-mentioned localities, especially in the Wisconsin district, where the calamine is known among the miners by the name of 'dry-bone.' But one of the most peculiar mineral deposits in the United States is that of the red oxide of zinc, and of Franklinite, which occur in Sussex County, New Jersey, at Sparta and Stirling. They are intercalated among the beds of a crystalline limestone, with a total thickness of above 30 feet, and are the scene of very successful undertakings.

Lastly, iron ores of various species, particularly the magnetic oxide and hæmatite, occur in numerous localities, Missouri is remarkable for large masses, and Lake Superior offers even a greater abundance.

A bed of magnetic oxide of iron occurs in gneiss near Franconia in New Hampshire. It has a width of from 5 to 8 feet; and has been mined through a length of 200 feet, and to a depth of 90 feet. The same ore is found in veins in Massachusets and Vermont, accompanied by copper and iron pyrites. It is met with in immense quantities on the western bank of the lake Champlain, forming beds of from 1 to 20 feet in thickness, almost without mixture, encased in granite. It is also found in the mountains of that territory. These deposits appear to extend without interruption from Canada to the neighbourhood of New York, where an exploration on them may be seen at Crown-Point. The ore there extracted is in much esteem. Several mines of the same species exist in New Jersey. The primary mountains which rise in the north of this state near the Delaware, include beds almost vertical of black oxide of iron, which have been worked to 100 feet in depth. In the county of Sussex the same ore occurs, accompanied with Franklinite. At Roxbury, in Connecticut, a good sized lode of sparry iron occurs; the only one of the kind known in the Alleghanies.

Although the mineral resources of Canada are remarkably rich and varied, mining operations have not yet been adequately carried out. Iron ores of great value, chiefly magnetic oxide and red hæmatite, are abundant in the Laurentian rocks at several points on the Ottawa, along the Rideau Canal, and near Marmora; but the want of coal has prevented their due development. Good iron ore is also found in many of the eastern townships, and bog ore has been smelted at the Radnor Forges, Batiscan. Copper ores are worked in Huronian rocks on the north-eastern shore of Lake Huron, and the ores of the eastern townships have been worked at Harvey's Hill, in Leeds, and at the Acton mine, now exhausted. Gold workings have been established on the Chaudière and its tributaries, whilst the metal was at one time worked at the Richardson mine, Hastings Co., where it was found curiously associated with lignite Veins of galena are found in the Laurentian rocks, but are not worked. Among the non-metallic minerals of the Dominion may be mentioned the fine deposits of phosphate of lime, or apatite, and mica. Petroleum is widely distributed in certain localities.

Coal seams of great value are actively worked in the provinces of New Brunswick and Nova Scotia; whilst gold is yielded by the quartz-veins of Waverley and other districts in Nova Scotia.

Before quitting America, it should be mentioned that the West India Islands offer indications of mineral. Many cupriferous veins have been explored in Jamaica. Copper ore and molybdenite occur at Virgin Gorda; and Cuba has for years been remarkable for the richness and abundance of its copper ores. The principal mine is the Cobre, worked on an extensive scale. The lodes, which have been very large at shallow depths, course E. and W. through greenstone and conglomeritic rock. The Santiago mines have also yielded a large amount of ore.

To R. W. Raymond, Ph.D., we are indebted for the following:—

Professor W. P. Blake, in a note to his 'Catalogue of California Minerals,' pointed out that the mining districts of the Pacific slope are arranged in parallel zones, following the prevailing direction of the mountain ranges. This interesting generalization has been more fully illustrated and connected with the geological history of the country by Mr. Clarence King, who sums up the observed phenomena as follows:—

'The Pacific coast-ranges upon the west carry quicksilver, tin, and chromic iron. The next belt is that of the Sierra Nevada and Oregon Cascades, which, upon their west slope, bear two zones, a foot-hill chain of copper mines, and a middle line of gold deposits. These gold-veins, and the resultant placer mines, extend far into Alaska, characterised by the occurrence of gold in quartz, by a small amount of that metal which is entangled in iron sulphurets, and by occupying splits in the upturned metamorphic strata of the Jurassic age. Lying to the east of this zone, along the east base of the Sierras, and stretching southward into Mexico, is a chain of silver mines, containing comparatively little base metal, and frequently included in volcanic rocks. Through Middle Mexico, Arizona, Middle Nevada, and Central Idaho is another line of silver mines, mineralised with complicated association of the base metals, and more often occurring in older rocks. Through New Mexico, Utah, and Western Montana, lies another zone of argentiferous galena lodes. To the east, again, the New Mexico, Colorado, Wyoming, and Montana gold-belt is an extremely well-defined and continuous chain of deposits.'

These seven longitudinal zones or chains of mineral deposits must not, in my opinion, be held to constitute a complete classification. The belts of the coast-range and the west slope of the Sierra are well defined, both geologically and topographically; but it is not so easy to separate into distinct groups the occurrences of gold and silver of the Sierra. For instance, the gold of Eastern Oregon, Idaho, and Western Montana, together with such occurrences in Nevada as those of the Silver Peak and New Pass districts, and numerous instances of sporadic occurrence of particular ores of silver or argentiferous base metals, cannot be brought within the classification above given. Either more zones must be recognised, or a greater mineralogical variety must be acknowledged in those already laid down. The latter alternative is, I think, the more reasonable. According to the principles set forth in a discussion of mineral deposits in my report for 1870,[1] it appears evident that the agencies which affect the general constitution of geological formations are far wider in their operation than those which cause the formation of fissures; and that the causes influencing the filling of fissures are still more local in their peculiarities than those which form the fissures themselves. Thus, of the area covered by rocks of a given epoch, more or less uniform in lithological character, only a small portion may have been exposed to conditions allowing deposits of useful minerals, even when such deposits are contemporaneous, as in the case of coal. Still more limited is the field for the formation of fissures; but it must be freely confessed that, in the case before us the corrugation of half the continent into parallel ranges offers good grounds for the expectation of vast longitudinal systems of fissures. When we come to consider the filling of these fissures, however, it is evident that the mineralogical character of the vein-material must vary, to some extent, as to the gangue, but to a still greater extent as to the nature of the ores. Even single mines, in the course of extensive exploitation, have produced ores differing as widely as do those of the different zones enumerated by Mr. King. I am, in fact, strongly inclined to consider freedom from base metals, for instance, a peculiarity due in many cases to secondary processes, and not to be relied upon as characteristic for single veins even, to say nothing of whole groups, districts, and continental zones.

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[1] 'Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains,' by R. W. Raymond, U. S. Commissioner of Mining Statistics.

Nevertheless, the generalisations of Professor Blake and Mr. King on this subject are highly interesting and valuable. The criticism here made is not in opposition to their views so much as in qualification of a possible rash application on the part of the general public. The zonal parallelism does exist, though in a somewhat irregular way; and it is clearly referrible, as these writers have shown, to the structural features of the country, the leading feature of which is the longitudinal trend of the mountain ranges.

Subordinate to this trend (or, more strictly, resulting from the same causes as produced it) appear the predominant longitudinal strike of the great outcrops of sedimentary rocks, the longitudinal axes of granite outbursts, and, finally, the longitudinal vents of lava-overflows and the arrangement of volcanos in similar lines. It is evident that in crossing the country from east to west we traverse a series of different formations; while, by following routes parallel with the main mountain ranges, we travel upon the continuous outcrops of the same general age.

Mr. King distinguishes in the history of the entire Cordillera two periods of disturbance, which have been accompanied by the rending of mountain chains, and the ejection of igneous rocks. Such periods would afford the conditions of solfataric action, thermal springs, and the generation of acid gases and metallic sublimates and solutions, and thus favour the formation of metalliferous deposits. The first of these periods, he says, culminated in the Jurassic, produced over the entire system a profound disturbance, and is, in all probability, the dating-point of a large class of lodes. To the second, or tertiary period, he assigns the mineral-veins which traverse the early volcanic rocks.

The expression 'culminated in the Jurassic' merely refers, no doubt, to the fact that the cretaceous strata of California repose unconformably upon the upturned and metamorphosed Jurassic slates, having been themselves neither tilted nor highly metamorphosed. Perhaps it is well to remember, however, that the cretaceous is a weak point in the California series, at least, as determined by leading fossils; and perhaps the results of more complete stratigraphical surveys will indicate that there are gaps of no little significance, dynamically and chronologically, in this part of the geological record. At all events, the period of the folding of the Sierra Nevada (presumably that of the formation of many metalliferous deposits) was in some sense post-Jurassic rather than Jurassic; and probably this is the meaning of Mr. King, who speaks of it in another passage as 'late Jurassic.'

The lodes which are referred to this period are of two types: first, those wholly inclosed in the granites, the outburst of which accompanied the upheaval of the earlier stratified group, or in the metamorphosed Jurassic or sub-Jurassic strata; secondly, those which occupy planes of stratification or jointure, thus following in general the dip and strike of the country-rock, while they present in other respects the indications of fissure-veins. The veins of the Reese-river granite are examples of the first type; many gold-veins of California, the Humboldt mines, &c., are given as illustrations of the second. The White Pine district, the mineral deposits of which are said to be inclosed conformably between strata of Devonian limestone, is declared to be a 'prominent example of the groups comprised wholly within the ancient rocks.'

We have hitherto supposed the strata immediately overlying the argentiferous limestone at White Pine to be deep-water Carboniferous; but their Devonian character seems to be demonstrated by Mr. Arnold Hague.[1] More practically important is the assignment of these deposits to the earlier period of geological disturbance.

Mr. King appears here to include in one group *all* the White Pine deposits, the 'Base Range,' as well as 'Treasury Hill'; yet the striking distinction in mineralogical character is worthy of regard. The deposits of Treasury Hill are notably free from base metals; and it seems to me that in their present form they must be due to a secondary action, which has concentrated and recombined the metallic elements of older deposits. It should be added, however, that although the chlorides of Treasury Hill are as pure as those of Lander Hill, they do not appear, like the latter, to yield in depth to such silver ores as characterize the fissure-veins of Reese-river district —ruby-silver, for instance. Nor are they fissure-veins, so far as we can now decide.

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[1] See volume on 'Mining Industry of the United States Geological Exploration of the Fortieth Parallel.'

To the tertiary period of orographical disturbance are referred the volcanic overflows and the veins wholly or partly inclosed in volcanic rocks. Under this head Mr. King classes many important veins of Mexico, several of those which border the Colorado river in the United States, and, in general, that zone which lies along the eastern base of the Sierra Nevada. The Comstock lode is adduced as the most prominent example of this type, and the Owyhee district in Idaho is also referred to it, because, although in granite, it presents a series of volcanic dykes, which appear to prove, by the manner of their intersections with the quartz lodes, that the latter are of tertiary origin. It will be seen that although the extent and number of the deposits of this class are inferior to those of the earlier period, they include some of the most brilliant instances in the history of mining. As Mr. King, however, points out, many of the veins which are wholly inclosed in the older rocks may nevertheless be due to this later period of disturbance. Nor does he ignore the bearing of this thought on his determination of the early period as Jurassic. He confesses that in more recent strata, formed from *débris* of Jurassic rocks, ore-bearing pebbles have not been found; but he regards this fact as a piece of negative evidence merely.

The distribution of mineral deposits east of the Rocky mountains follows somewhat different laws. Here we have but one longitudinal range, that of the Alleghanies, which is accompanied by a gold-bearing zone of irregular extent and value. In the Southern States the strata flanking this range present a remarkable variety of mineral deposits. On the eastern slope of the Rocky mountains, again, occurs what may perhaps be denominated a zone or longitudinal series of coal-fields. But between these mountain boundaries the geological formations of the country cluster, as it were, around centres or basins. We have such a group in Michigan, another in the Middle States, and a third in the South-west.

The deposits of the different metals, ores, and useful minerals, in the country east of the Rocky mountains, vary widely in age. The ores of gold, copper, and iron, in the pre-Silurian schists of the south; the galena and cobalt ores of the south-west, and the copper ores of Lake Superior, in the lower Silurian rocks; the argillaceous iron ores of New York, and other States west of New York, in the upper Silurian, and the salines of the same group; the bitumen, salt, coal, and iron ores of the Subcarboniferous; the coal and iron of the Carboniferous; the coal, copper, and barytes of the Triassic; the lignites of the Cretaceous; and the fossil phosphates of the Tertiary period; are instances which may serve to show how great is this variety. It is not within the province of this paper to discuss the mineral deposits of the Mississippi basin, the Appalachian chain, or the Atlantic coast. I shall content myself with brief mention of two points. The first is the greater relative age of the metalliferous deposits as compared with those of the inland basin and the Pacific slope. On this side the period of greatest activity in such formations was over before it began in the west. The great gold and silver deposits beyond the Rocky mountains appear to be post-Devonian, post-Jurassic, and even Tertiary in their origin. The vast volcanic activity which affected so wide an area in California, Oregon, Washington, Idaho, and Nevada, is not represented in the east.

The other point is the peculiar relative position of our coal and iron deposits. This was eloquently described by Mr. Abrams Hewitt, United States Commissioner to the Paris Exposition, in his admirable review of the iron and steel industry of the world. I cannot do better than quote his forcible words:—

'The position of the coal-measures of the United States suggests the idea of a gigantic bowl filled with treasure, the outer rim of which skirts along the Atlantic to the Gulf of Mexico, and thence, returning by the plains which lie at the eastern base of the Rocky mountains, passes by the great lakes to the place of beginning, on the borders of Pennsylvania and New York. The rim of the basin is filled with exhaustless stores of iron ores of every variety, and of the best quality. In seeking the natural channels of water-communication, whether on the north, east, south, or west, the coal must cut this metalliferous rim; and, in its turn, the iron ore may be carried back to the coal, to be used in conjunction with the carboniferous ores, which are quite as abundant in the United States as they are in England, but hitherto have been left unwrought, in consequence of the cheaper rate of procuring the richer ores from the rim of the basin. Along the Atlantic slope, in the highland range, from the borders of the Hudson river to the state of Georgia, a distance of 1,000 miles, is found the great magnetic range, traversing seven entire States in its length and course. Parallel with this, in the great limestone valley which lies along the margin of the coal-field, are the brown hæmatites, in such quantities at some points, especially in Virginia, Tennessee, and Alabama, as to fairly stagger the imagination.

And, finally, in the coal-basin is a stratum of red fossiliferous ore, beginning in a comparatively thin seam in the state of New York, and terminating in the state of Alabama in a bed 15 feet in thickness, over which the horseman may ride for more than 100 miles. Westward, in Arkansas and Missouri, is reached that wonderful range of red oxide of iron, which, in mountains rising hundreds of feet above the surface, or in beds beneath the soil, culminates at Lake Superior in deposits of ore which excite the wonder of all beholders; and returning thence to the Atlantic slope, in the Adirondacks of New York, is a vast, undeveloped region, watered by rivers whose beds are of iron, and traversed by mountains whose foundations are laid upon the same material. In and among the coal-beds themselves are found scattered deposits of hæmatite and fossiliferous ores, which, by their proximity to the coal, have inaugurated the iron industry of our day.'

MINES OF AUSTRALIA.

Victoria is essentially a gold-producing colony, extensive mining operations having for many years been systematically carried on not only in the alluvial drifts and deep 'leads,' but also in the auriferous quartz-reefs which course through lower Silurian rocks. Silver ores have been worked by the St. Arnaud Silver Mines Company. Stream-tin, in the form of 'black-sand,' is frequently found in connection with the alluvial gold, and veins of tin ore have also been discovered. Copper and lead, though found in the colony, are not abundant; nor is the iron worked, although in the form of titaniferous iron-sand it enjoys a wide distribution. Mining for coal has been attempted at Western Port, Cape Otway, and at some other localities; but a Board recently appointed to enquire into the coal-producing resources of the colony have reported unfavourably. A thick deposit of lignite has been worked at Lal Lal.

South Australia is remarkably rich in copper, the Burra Burra mines being celebrated for their production of malachite, or green carbonate. Several copper mines are also established on Yorke's Peninsula, and are notable for yielding the oxychloride of copper, or *atacamite*. Among the principal copper mines may be mentioned the Wallaroo, the Kapunda and Moonta mines. The colony also possesses magnificent iron ores in the form of magnetite and red and brown hæmatite, but they are not yet worked to any extent. Gold, silver, and bismuth, are to be mentioned among the useful minerals of South Australia.

In New South Wales coal-measures are worked at Newcastle, Wollongang, and Hartley. Oil-shales are also wrought at some of these localities, and distilled for sake of the kerosine oil which they yield. The iron of the colony is not yet largely worked. Copper mines are opened up to a limited extent, and gold mining is not neglected. Valuable deposits of tin ore were discovered in the Northern districts of the colony in 1870, and are being actively developed. The tin extends into the adjacent colony of Queensland.

Queensland is rich in coal, some of which appears to be of palæozoic and some of mesozoic age. Gold is worked both in reefs and in alluvial deposits. Copper ores are mined at Peaks Down and Mount Perry; and the iron ores have recently received attention, whilst the discovery of tin is being eagerly followed up by the miner. Agates, chrysoprase, and opal must also be enumerated among the mineral products of this colony,

In Tasmania tin ore has recently been worked in the neighbourhood of Mount Bischoff. Coal occurs on the Mersey river and elsewhere; some of the Tasmanian coal is bituminous, and some anthracitic, whilst other varieties are merely lignite. A peculiar bituminous substance, known as *Tasmanite*, occurs on the Mersey.

New Zealand is rich in mineral wealth. Gold has been successfully worked in some parts of the colony, as at the Thames gold-fields. Bituminous coal occurs in the Pukawan coal-field, whilst lignite is widely distributed in the North and Middle Islands, and is often associated with a fossil gum or *retinite*. Copper ores occur in the serpentine of the Dunn Mountain, and titaniferous iron-sand skirts the shore of Taranaki. Among the other mineral products may be mentioned chrome iron ore, arsenic, graphite, and jade.

ON SOME OTHER LESS KNOWN MINE COUNTRIES.

The islands of Cyprus and Negropont, in the Mediterranean, were celebrated, in former times, for their copper mines; and several islands of the Archipelago presented gold mines, now abandoned. The same thing may be said of Macedonia and Thrace. The mountains of Servia and Albania contain iron mines; and lead mines occur in Servia, and the adjacent provinces of European Turkey. The silver mines of Laurium, in Attica, used in early times to form a most important source of revenue to Athens. These are now being partially reworked. Mines of silver ore, with galena, are still worked at Keban Maden and Ghumush Khaneh in Asia Minor; whilst that of copper at Arghaneh Maden, in the Taurus, yields a large supply of the ores of that metal, which are refined at Tocat. Some also occur in Arabia and in Persia; and in the territories round the Caucasus. Persia has mines of argentiferous lead a few leagues from Ispahan; and Natolia, or Asia Minor, furnishes orpiment and chrome iron ore.

Thibet passes for being rich in gold and silver mines. China produces a great quantity of iron and mercury. The copper mines of this empire lie principally in the province of Yu-Nan and the island Formosa. Japan, likewise, possesses copper mines in the provinces of Kijunack and Sarunga. They seem to be abundant; and are now being explored. Japan presents, moreover, mines of quicksilver, also mines of gold, silver, tin, red sulphide of arsenic, &c. But in China, as in Europe, coal is the most important of the mining products. This combustible is explored, especially in the environs of Pekin, and in the northern parts of the empire. See COAL.

Iron mines exist in several points of the Burman empire, and of Hindostan. Near Madras, there exist excellent ores of sparry iron, and black oxide, analogous to the Swedish ores. The islands of Macassar, Borneo, and Timor, include copper mines. The tin obtained from the islands of Banca and Billiton, and from the peninsula of Malacca, and several other points of Southern Asia, proceeds entirely from the washing of sands. The same is undoubtedly true of the gold furnished by the Philippine Isles, Borneo, &c. It appears, however, that mines of gold and silver are worked in the island of Sumatra.

In Africa, large quantities of gold are washed by the natives from the alluvium. Some interest has recently been excited by the discovery of gold-fields in South Africa, near the frontier of the Transvaal Republic.

Near the Cape of Good Hope, in Namaqualand, numerous indications of copper ore are met with, which, in a few instances only, have led to the opening of remunerative mines. At Bembi, near Ambriz, a powerful vein of malachite has been rudely worked by the negro chiefs, and is now leased to an English company by the Portuguese Government. It is asserted that a great deal of copper exists in Abyssinia. On the banks of the Senegal, the Moors and the Pouls fabricate iron in travelling forges. They employ as the ore the richest portions of a ferruginous sandstone, which seems to be a very modern formation. Morocco appears to contain ores of various metals; and Algeria, since it has been in the hands of the French, has given rise to active explorations, among which may especially be mentioned the copper mines of Tenes.

For a description of the South African diamond mines, see DIAMOND.

MINES OF THE CALCAREOUS MOUNTAINS OF ENGLAND.

The limestone formation immediately subjacent to the coal-measures, or the carboniferous limestone, constitutes almost alone several mountainous regions of England and Wales; in which three districts very rich in lead mines deserve to be noted.

The first of these districts, Alston Moor, comprehends the upper parts of the valleys of the Tyne, the Wear, and the Tees, in the counties of Cumberland, Durham, and York. Its principal mines are situated near the small town of Alston, in Cumberland. The veins of galena which form the object of the workings, traverse alternate beds of limestone, shale, and sandstone; and are very remarkable for their becoming suddenly thin and impoverished on passing from the limestone into the shale or sandstone; and for resuming their richness, and usual size, on returning into the limestone. The exploitations are situated in the flanks of considerably high hills, bare of wood, and almost wholly covered with marshy heaths. The waters are drawn off by long adit-levels; and the ores are dragged out by horses to the day. The galena extracted from these mines is smelted by means of coal and a little peat, in furnaces of Scotch construction. The lead is very poor in silver; but most of it is now treated by the Pattinson process. The mines of this district produce annually about 25,000 tons of lead. Copper ores have been raised, although not in large quantity, from a very strong vein, containing chiefly iron pyrites and some galena, about six miles south-west of Alston.

This region is bounded by the Cross Fell range on the west, and extends southward to the Yorkshire valleys of Swaledale, Arkendale, &c., to Grassington, where numerous lead mines are worked under very similar circumstances. The Yorkshire mines yielded in 1856, 8,986 tons of lead.

The second metalliferous district lies in the northern part of Derbyshire, and in the conterminous parts of the neighbouring counties. The districts called the Peak and King's-Field are the richest in workable deposits. The mines of Derbyshire are getting exhausted; they are very numerous, but in general inconsiderable. The galena extracted from them is treated with coal in reverberatory furnaces; but the silver is very small in quantity. They yield annually 5,000 tons of lead; with a certain quantity of calamine, and a little copper ore. At Ecton, in North Staffordshire, a remarkably rich copper mine was worked in the last century, at the intersection of several veins, in the midst of very contorted beds of grey and black limestone.

The veins of both the above districts are noted for the beauty of the fluor, calcspar, and other crystallised minerals accompanying the galena; and those of Derbyshire, also, for the thinning or partial interruption which they suffer in crossing the 'toadstone,' a rock of igneous origin, which is interstratified with the limestone. Besides the lodes or 'rake-veins,' the less normal forms of repository termed 'flats' and 'pipe-veins' yield in both these districts large amounts of ore.

The third metalliferous district is situated in Flintshire and Denbighshire, counties forming the N.E. part of Wales. Next to Alston Moor this is the most productive; furnishing annually nearly 6,000 tons of lead, and a certain quantity of calamine. The galena is smelted in reverberatory furnaces, and affords a lead far from rich in silver, which was therefore seldom subjected to cupellation, until the introduction of Pattinson's process of desilverising. The lodes, coursing E. and W., are intersected by several great cross veins, which may be traced for many miles, and only exceptionally yield ore. None of the lead veins appear to be prolonged into the subjacent slate rocks. At the Orme's Head, cupriferous veins have also been worked in the limestone.

Mines of galena and calamine have, from a very early period, been worked in the Mendip Hills, to the south of Bristol, but are now almost entirely idle.

Besides the metallic mines just enumerated, the formation of the metalliferous limestone presents, in England, especially in the counties of Northumberland and Cumberland, seams of coal, generally very thin and anthracitic. Far more important are the red and brown oxides of iron, which this formation yields in vast quantity; the brown ore in beds and veins in Alston Moor; hæmatite of the richest kind, in irregular deposits, near Whitehaven, Cumberland, and at Ulverstone, Lancashire; in less important repositories in Derbyshire, Flintshire, and on the flanks of the Mendip Hills; and, lastly, excellent brown peroxide in the upper limestone environing the Forest of Dean, where it occupies a series of devious caverns and holes lying more or less in the same plane. Appearances of the same kind, but on a smaller scale, fringe the southern side of the South Welsh coal-field.

MINES OF THE LATER ROCK FORMATIONS.

The most important mines of what used to be termed, in the earlier days of geology, the Secondary rocks, and perhaps of all mineral formations whatsoever, are those worked in the most ancient strata of that division, in the coal-measures. Since, however, the organic contents of the rocks have been more fully studied and compared, the coal-measures have been classed with the Palæozoic systems, and that supposed line of demarcation between them and the older strata already treated of, can only be retained as a matter of convenience, and as marking in most countries a great change in the character of the mineral contents as we ascend in the geological scale.

The British islands, France and Germany, frequently present ranges of the older rocks, upon the flanks of which, sometimes unconformably, repose the deposits of coal. The principal of these have become great centres of manufacture; for Newcastle, Birmingham, Glasgow, Sheffield, St. Etienne, &c., owe their prosperity and their rapid enlargement to the coal raised as it were at their gates in enormous quantities. Lancashire, Wales, Belgium, and Silesia, owe equally to their extensive collieries a great portion of their activity, their wealth, and their population. Other coal districts, less rich, or mined on a less extensive scale, have procured for their inhabitants less distinguished, but by no means inconsiderable, advantages; such, for example, in Great Britain, are Derbyshire, Cheshire, Shropshire, Warwickshire, the environs of Bristol, &c.; some parts of Ireland; in France, Litry, department of Calvados, Comanteric, Alais, le Creuzot, &c.; in Rhine Prussia, Saarbrück, and Westphalia; and several localities in Saxony, Bohemia, Spain, Portugal, the United States, &c.

We need not enter here into ampler details on coal mines; these particulars are given in the article COAL.

Nature has frequently deposited close to the coal, an ore, whose intrinsic value alone is very small, but whose abundance in the neighbourhood of fuel becomes extremely precious to man; we allude to the clay-ironstone of the coal-measures. It is extracted in enormous quantities from the coal-fields of Scotland, Yorkshire, Staffordshire, Shropshire, and South Wales. Much of it is also raised from the coal-strata of Silesia and of Westphalia, but few coal-fields appear to be entirely deficient of it. The iron works of England, which are supplied in great part from this ironstone reduced with coke or coal, pour annually into commerce six millions and a half tons of pig iron.

The shale, or slate-clay, of the coal-measures contains sometimes a very large quantity of pyrites, which decomposing by the action of the air, with or without artificial heat, produces sulphate of iron, and sulphate of alumina, whence copperas and alum are manufactured in great abundance.

The calcareous formation which surmounts the coal-measures, called by geologists *Zechstein*, magnesian limestone, and older Alpine limestone, contains different deposits of metallic ores; the most celebrated being the cupreous schist of Mansfeld, a stratum of slightly calcareous slate, from a few inches to 2 feet thick, containing copper pyrites in sufficient quantity to afford 2 per cent. of the weight of the ore of an argentiferous copper. This thin layer displays itself in the north of Germany over a length of eighty leagues, from the shores of the Elbe to the banks of the Rhine. Notwithstanding its thinness and relative poverty, skilful miners have contrived to establish, on different points of this slate, a number of important explorations, the most considerable being in the territory of Mansfeld, particularly near Rothenburg. They produce annually 2,000 tons of copper, and 20,000 marcs of silver. We may also mention those of Hessia, situated near Frankenberg, Bieber, and Riegelsdorf. In the latter, the cupreous schist and its accompanying strata are traversed by veins of cobalt, mined by the same system of underground workings as the schist. These operations are considerable; they extend, in the direction of the strata, through a length of 8,700 yards, and penetrate downwards to a very great depth. Three galleries of efflux are to be observed; two of which pour their waters into the Fulde, and the third into the Verra. These mines have been in activity since the year 1530. Analogous mines exist near Saalfeld in Thuringia.

A very remarkable deposit of the same period, whence geologists have given this formation the name of Permian, occurs in the Russian government of Perm, the sandstones containing disseminated particles of copper ore, chiefly in the form of carbonate, to the distance of 400 or 500 wersts from the chain of the Oural. Some of the thick flaggy grey grits contain as much as 2½ per cent. of copper, and the imperial zavods near Perm are stated to yield 260 tons annually from this source.

To the same geological formation must probably be referred the limestone which contains the sparry iron mine of Schmalkalden at the western foot of Thuringerwald, where there has been explored from time immemorial a considerable mass of this ore, known by the name of *Stahlberg*. The working has been executed in the most irregular manner, and has opened up enormous excavations; whence disastrous 'runs' have taken place in the mines.

At Tarnowitz, 14 leagues S.E. of Oppeln in Siberia, the zechstein contains, in some of its strata, considerable quantities of galena and calamine; into which mines have been opened, that yield annually from 600 to 700 tons of lead, 1,000 to 1,100 marcs of silver, and much calamine. Mines of argentiferous lead are noticed at Olkutch and Jaworno in Gallicia, about 6 leagues N.E. of Cracow, and 15 leagues E.N.E. of Tarnowitz. From their position these have been referred to the same period. The important lead mines of Villach and Bleiberg in Carinthia have been shown by the Austrian geologists to belong to a rather more recent formation, whilst several minor lead-bearing localities of the same province occur in the Hallstadt limestone (Upper Trias), and Gailthal limestone (carboniferous).

There has been discovered near *Confolens* in the department of *la Charente*, in a secondary limestone, calcareous beds, and particularly subordinate beds of quartz, which contain considerable quantities of galena. At *Figeac* also, in the department of *le Lot*, deposits of galena, blende, and calamine occur in a secondary limestone. At *la Voulte*, on the banks of the Rhône, there is mined, in the lower courses of the limestones that constitute a great portion of the department of the Ardèche, a powerful bed of iron ore.

It used to be supposed that it is in the zechstein, or in the sandstones and trap rocks of nearly the same age, that the four great deposits of the sulphuret of mercury, of *Idria*, the *Palatinate*, *Almaden*, and *Huancavelica* are mined, but more recent observations would place some of them, at least, in rocks contemporaneous with the coal-measures. See MERCURY.

The formation which separates the *Zechstein* from the *lias* (*calcaire à gryphites*), called New Red Sandstone and Red Marl in England, and *Bunter-sandstein*, *Muschelkalk*, and *Keuper* in Germany, presents hardly any important mines except those of rock-salt; which enrich it in Cheshire, and in many parts of continental Europe. The mines of Salzburg belong to a formation somewhat higher, and those of Wieliczka, Bochnia and of Transylvania, as well as of Cardona in Spain, are of Tertiary date. The copper-bearing sandstones of *Alderley Edge*, in Cheshire, are of Triassic age, and at *Mechernich*, in Rhenish Prussia, galena is worked in a conglomerate belonging to the Bunter series.

The lias often contains very pyritous lignites and shales, which are mined in many places, and particularly at Whitby and Guisborough in Yorkshire, for the manufacture of alum and copperas.

Within the last few years, most important beds of stratified iron ore have been worked in the marlstone, or middle lias in Cleveland, in the north of Yorkshire.

Strata of iron ore also occur in the overlying oolitic limestones, in Yorkshire, Northamptonshire, and other parts of England. The same formations have in France long been noted for the supply of large quantities of iron ore.

The Lower Greensand beneath the chalk formation is often so strongly imbued with iron as to have led in former times to extensive mining operations and iron smelting in the south-eastern part of England. Since the general introduction of railways, attempts have again been made to utilise those iron deposits.

The lowest beds of the chalk contain iron pyrites, which has become the object of an important exploration at *Vissans*, on the southern coast of the *Pas-de-Calais*, where it is converted into sulphate of iron. The waves turn the nodules out of their bed, and roll them on the shore, where they are picked up.

If the chalk be poor in useful minerals, this is not the case with the tertiary formation above it; for it contains important mines. In it are explored numerous beds of lignite (wood-coal), and from some of these lignite deposits, also, yellow amber is extracted. The iron mines of the north-east of Ireland, previously noticed, are in deposits of basalt of miocene age.

The other tertiary formations present merely a few mines of sulphur, of iron and bitumen; but it must here again be remarked, that many of the secondary, and even of the tertiary strata have in certain countries been subjected to metamorphic action, of such a nature as to have led to their being classed with the older rocks; and thus some of the metalliferous formations of the east of Europe and of South America, although still somewhat obscure, ought without doubt in strictness to be classified with these more recent deposits.

Several of the secondary or tertiary strata contain deposits of sulphur, which are mined in various countries.

The formations of a decidedly volcanic origin afford but few mining materials, if we except sulphur, alum, and opals.

MINES OF THE ALLUVIAL STRATA.

This formation contains very important mines, since from it are extracted all the diamonds, and almost all the precious stones, the platinum, and the greatest part of the gold, with a considerable portion of the tin. The diamond mines are confined nearly to Brazil, and to the kingdoms of Golconda and Visapour in the East Indies. The South-African diamonds are found partly in river-beds, and partly in 'dry diggings.' See DIAMOND.

The tin-stream works of Cornwall, Bohemia, and the East Indies, and the gold-washings, placers, or 'diggings' of Siberia, Borneo, California, and Australia, belong to beds of alluvium or drift, irregularly deposited over the older formations. See GOLD; TIN.

MINING. As the operations of mining vary with the conditions of the rock-formations, in which the minerals sought for by the miner occur, it is necessary to give a brief description of the more especially marked distinctions which are seen in our geological formations.

Geologists divide rocks into *stratified* and *unstratified*. Those mineral systems, which consist of parallel, or nearly parallel planes, whose length and breadth greatly exceed their thickness, are called *stratified* rocks; while to those which occur in thick blocks, and which do not exhibit those parallel planes, the term of *unstratified* rocks is applied. These formations have been divided into two other classes, namely, the *primary* and the *secondary*. The advances of geological science, however, and more accurate information, have materially modified the views which gave rise to those divisions; and when men have learned to look on great natural phenomena without the interposition of the medium of some favourite theory, there is but little doubt the interpretation will be somewhat different from even that which is now received.

A certain set of rocks may be classed as of truly igneous origin. These are the traps, basalt, and the like. These have often been termed primary rocks. Yet we have rocks of this class, not merely forcing their way through the superincumbent and more recent rocks, but actually overflowing them; they in many cases, therefore, are much more recent than the secondary rocks. Granite has commonly been classed as a truly igneous rock; but facts have lately been developed which show, at all events, the combined action of water. See GRANITE.

Granite is usually classed with the unstratified rocks; but the section of any granite quarry will exhibit very distinct lines, conforming, more or less, to the horizontal—known to the quarrymen as the *bedway*—which would appear almost sufficient to place those rocks for certain purposes amongst the stratified ones.

It is commonly stated that the unstratified rocks possess a nearly vertical position, the stratified rocks assuming more nearly a horizontal one. There are numerous examples adverse to this view; indeed, it must be regarded as a hasty generalisation—the bedway of the granite approaching very nearly to the horizontal, while we often find the truly stratified rocks in a vertical position.

Where the older rocks graduate down into the plains, rocks of an intermediate character appear, which, though possessing a nearly vertical position, like the unstratified and non-fossiliferous rocks, contain a few vestiges of animal beings. These were formerly called *transition*, to indicate their being the passing links between the first and second systems of ancient deposits; some of them are distinguished by their fractured and cemented texture, for which reason they are sometimes called *conglomerate.* These transition rocks form part of the *Palæozoic* series of modern geologists.

Between the older and the secondary rocks, another very valuable series is interposed in certain districts of the globe; namely, the coal-measures, the paramount formation of Great Britain. The coal-strata are frequently disposed in a basin-form, and alternate with parallel beds of sandstone, slate-clay, ironstone, and occasionally of limestone.

As a practical rule it may be here stated that, in every mineral formation, the inclination and direction are to be noted; the former being the angle which it forms with the horizon, the latter the point of the azimuth or horizon towards which it dips, as west, north-east, south, &c. The direction of a bed is that of a horizontal line drawn in its plane; and which is also denoted by the point of the compass. Since the lines of direction and inclination are at right angles to each other, the first may always be inferred from the second; for when a stratum is said to dip to the east or west, this implies that its direction is north and south.

The following terms have been used to express dissimilar conditions in mineral deposits, well known to the practical miner.

Masses are mineral deposits, not extensively spread in parallel planes, but irregular heaps, rounded, oval, or angular, enveloped in whole or in a great measure by rocks of a different kind. Lenticular masses, being frequently placed between two horizontal or inclined strata, have been sometimes supposed to be stratiform themselves, and have been accordingly denominated by the Germans *liegende Stocke, lying-heaps,* or *blocks.*

The orbicular masses often occur in the interior of unstratified mountains, or in the bosom of one bed. These frequently indicate pre-existing cavernous spaces, which have been filled in with metalliferous or mineral matter.

Nests, Concretions, or *Nodules,* are small masses found in the middle of strata; the first being commonly in a friable state; the second often kidney-shaped, or tuberous; the third nearly round and encrusted, like the kernel of an almond.

Lodes, or *Veins,* are flattened masses, with their opposite surfaces not always parallel. These sometimes terminate like a wedge, at a greater or less distance, and do not run parallel with the rocky strata in which they lie, but cross them in a direction not far from the perpendicular; often traversing several different mineral planes. The *lodes* are sometimes deranged in their course, so as to pursue for a little way the space between two contiguous strata; at other times they divide into several branches. The matter which fills the lodes is for the most part entirely different from the rocks they pass through, or at least it possesses peculiar features.

This mode of occurrence suggests the idea of clefts or rents having been made in the stratum posterior to its consolidation, and of the vacuities having been filled with foreign matter, either immediately or after a certain interval. There can be no doubt as to the justice of the first part of the proposition, for there may be observed round many lodes undeniable proofs of the movement or dislocation of the rock; for example, upon each side of the rent, the same strata are no longer situated in the same plane as before, but make greater or smaller angles with it; or the stratum upon one side of the lode is raised considerably above, or depressed considerably below, its counterpart upon the other side. With regard to the manner in which the rent has been filled, different opinions may be entertained. In the lodes which are widest near the surface of the ground, and graduate into a thin wedge below, the foreign matter would seem to have been introduced as into a funnel at the top, and to have carried along with it portions of rounded gravel, and sometimes, though rarely, organic remains. In other, but very exceptional, cases, lodes are largest at their under part, and become progressively narrower as they approach the surface. From this circumstance, it has been inferred that the rent has been caused by an expansive force acting from within the earth; and that the foreign matter, having been in a fluid state, has afterwards slowly crystallised. Accurate observation shows that in the large majority of cases the metalliferous deposits are of aqueous, and not of igneous origin.

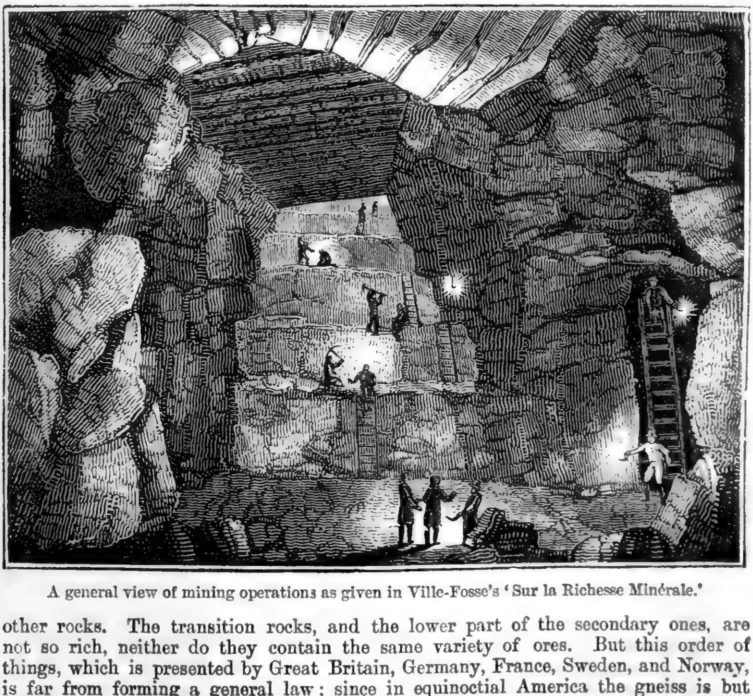
In the lodes, the principal matters which fill them are to be distinguished from the accessory substances; the latter being distributed irregularly, amidst the mass of the first, in crystals, nodules, grains, seams, &c. The non-metalliferous portion, which is often the largest, is called *gangue*, from the German *Gang*, vein. The position of a vein is denoted, like that of the stratum, by the angle of inclination, and the point of the horizon towards which it dips, whence the direction is deduced. In popular language a *lode* may be described to be a crack or fissure, such as is formed in the drying of a pasty mass, extending over a considerable extent of country, and penetrating to a great depth into the earth.

A metalliferous substance is said to be *disseminated* when it is dispersed in crystals, spangles, scales, globules, &c., through a large mineral mass. Tin is not unfrequently thus disseminated through granite and clay-slate rocks.

Certain ores which contain the metals most indispensable to human necessities, have been treasured up by the Creator in very bountiful deposits; constituting either great masses in rocks of different kinds, or distributed in lodes, veins, nests, concretions, or beds with stony and earthy admixtures; the whole of which become the objects of mineral exploration. These stores occur in different stages of the geological formations; but their main portion, after having existed abundantly in the several orders of the older strata, cease to be found towards the middle of the secondary rocks. Iron ores are, with a few exceptional cases, the only ones which continue among the more modern deposits, even so high as the beds immediately beneath the chalk, when they exist almost entirely as colouring-matters of the tertiary beds.

Granite, gneiss, mica, and clay-slate, constitute in Europe the grand metallic domain. There is hardly any kind of ore which does not occur in these in sufficient abundance to become the object of mining operations, and many are found in no other rocks. The transition rocks, and the lower part of the secondary ones, are not so rich, neither do they contain the same variety of ores. But this order of things, which is presented by Great Britain, Germany, France, Sweden, and Norway, is far from forming a general law; since in equinoctial America the gneiss is but little metalliferous; while the superior strata, such as the clay-schists, the syenitic porphyries, the limestones, which complete the transition series, as also several secondary

1446



A general view of mining operations as given in Ville-Fosse's 'Sur la Richesse Minérale.'

deposits, include the greater portion of the immense mineral wealth of that region of the globe.

All the substances of which the ordinary metals form the basis, are not equally abundant in nature; a great proportion of the numerous mineral species which figure in our classifications are mere varieties scattered up and down in the cavities of the great masses or lodes. The workable ores are few in number, being mostly sulphides, oxides, and carbonates. These occasionally form of themselves very large masses, but more frequently they are blended with lumps of quartz, felspar, and carbonate of lime, which form the main body of the deposit. The ores in that case are arranged in small layers parallel to the strata, or in small veins which traverse the rock in all directions, or in nests or concretions stationed irregularly, or finally disseminated in hardly-visible particles. These deposits sometimes contain only one species of ore, sometimes several, which must be mined together, as they seem to be of contemporaneous formation; whilst in other cases they are separable, having been probably formed at different epochs.

In mining, as in architecture, the best method of imparting instruction is to display the master-pieces of the respective arts. It is not so easy, however, to represent at once the general effect of a mine as it is of an edifice; because there is no point of sight from which the former can be sketched at once, like the latter. The subterranean explorations certainly afford some of the finest examples of the useful labours of man; but, however curious and grand in themselves, they cannot become objects of a panoramic view. It is only by the lights of geometry and geology that mines can be contemplated and surveyed, either as a whole or in their details; and, therefore, these marvellous subterranean regions, in which roads are cut which, with their sinuosities, extend at different levels over many hundred miles, are altogether unknown or disregarded by men of the world. Should any of them, perchance, from curiosity or interest, descend into these dark recesses of the earth, they are prepared to discover only a few insulated objects, which they may think strange or possibly hideous; but they cannot recognise either the symmetrical disposition of mineral bodies, or the laws which govern geological phenomena, and serve as sure guides to the skilful miner in his adventurous search. It is only by exact plans and sections of subterraneous workings, that a knowledge of the nature, extent, and distribution of mineral wealth can be acquired.

General Observations on the Localities of Ores, and on the Indications of Metallic Mines.

1. *Tin* exists in the primary rocks, appearing either in interlaced veins, in beds, as a constituent part of the rock itself, or in distinct veins. Tin ore is found in alluvial land, filling up low situations between lofty mountains; but this tin (stream-tin) has been derived from the older rocks of the neighbourhood. See TIN.

2. *Gold* occurs either in beds, or in veins, frequently in primary rocks; though in other formations, and particularly in alluvial deposits, it is also found. When this metal exists in the bosom of primitive rocks it is particularly in schists; it is not found in serpentine, but it is met with in greywacke in Transylvania. The gold of alluvial districts, called stream-gold or placer-gold, occurs, as well as alluvial tin, among the *débris* of the more ancient rocks. See GOLD.

3. *Silver* is found, particularly in veins and beds, in primitive and transition formations; though some veins of this metal occur in secondary strata. The rocks richest in it are gneiss, mica-slate, clay-slate, greywacke, and old alpine limestone. Localities of silver ore itself are not numerous, at least in Europe, among secondary formations; but silver occurs in combination with the ores of copper or of lead. See SILVER.

4. *Copper* exists in the three mineral epochs: 1, in primary rocks, principally in the state of copper pyrites, in lodes or veins; 2, in transition districts, sometimes in masses, usually in veins of copper pyrites; 3, in secondary strata, especially in beds of cupreous schist. The *Kupferschiefer* is, however, of palæozoic age, but copper ores are also found in true secondary strata, as at Alderley Edge. See COPPER.

5. *Lead* occurs, also, in each of the three mineral epochs; abounding particularly in primary and transition grounds, where it usually constitutes lodes, and occasionally beds of sulphide of lead (galena). The same ore is found in strata or in veins among secondary rocks, associated now and then with ochreous iron-oxide and calamine (carbonate of zinc); and it is sometimes disseminated in grains through more recent strata. See LEAD.

6. *Iron* is met with in four different mineral eras, but in different ores. Among primary rocks magnetic iron ore and specular iron ore occur chiefly in beds, sometimes of enormous size; the ores of red or brown oxide of iron (hæmatite) are found

sometimes in veins, but occasionally in very large masses, both in primitive and transition rocks; as also sometimes in secondary strata; but more frequently in the coal-measure strata, as beds of clay-ironstone, or globular iron oxide, and carbonate of iron. In alluvial districts we find ores of clay-ironstone, granular iron ore, bog-ore, swamp ore, and meadow ore. The iron ores which belong to the primitive period have almost always the metallic aspect, with a richness amounting to 75 per cent. of iron, while the ores in the posterior formations become, in general more and more earthy, down to those in alluvial soils, some of which present the appearance of a common stone, and afford not more than 20 per cent. of metal, though its quality is often excellent. See Iron.

7. *Mercury* occurs principally among secondary strata, in disseminated masses, along with combustible substances; though the metal is met with occasionally in primitive countries. See Mercury.

8. *Cobalt* belongs to the three mineral epochs; its most abundant deposits are veins in primary rocks; small veins containing this metal are found, however, in secondary strata.

9. *Antimony* occurs in lodes among the older and transition rocks.

10, 11. *Bismuth* and *Nickel* do not often constitute the predominating substance of any mineral deposits; but they commonly accompany cobalt.

12. *Zinc* occurs in three several formations, namely: as sulphide or blende, particularly in primary and transition rocks; as calamine, in secondary strata, usually along with oxide of iron, and sometimes with sulphide of lead.

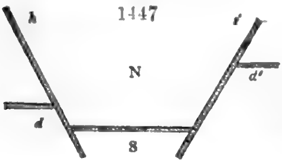
The study of the mineral substances, called *gangues* or vein-stones, which usually accompany the different ores, is indispensable in the investigation and working of mines. These *gangues*, such as quartz, calcareous spar, fluor spar, heavy spar, &c., and a great number of smaller substances, although of small value in themselves, become of great consequence to the miner, either in pointing out by their presence that of certain useful minerals, or by characterising in their several associations different deposits of ores of which it may be possible to follow the traces, and to discriminate the relations, often of a complicated kind, provided we observe assiduously the accompanying *gangues*.

Among the indications of mineral deposits, some are proximate, and others remote. The proximate are an efflorescence, so to speak, of the subjacent metallic masses; the frequent occurrence of fragments of particular ores, &c. The remote indications consist in the geological character, and in the nature of the rocks. From the examples previously adduced, marks of this kind acquire new importance when, in a district susceptible of including deposits of workable ores, the *gangues* or vein-stones are met with which usually accompany any particular metal. The general aspect of mountains whose flanks present gentle and continuous slopes, the frequency of sterile veins, the presence of metalliferous sands, the neighbourhood of some known locality of an ore; but when ferruginous or cupreous waters issue from sands or clays, such characters merit in general little attention, because the waters may flow from a great distance. No greater importance can be attached to metalliferous sands and saline springs.

In speaking of remote indications, we may remark that in several places, and particularly near Clausthal in the Hartz, a certain ore of oxide of iron occurs above the most abundant deposits of the ores of lead and silver; whence it has been named by the Germans the *iron-hat*. It appears that the iron ore rich in silver, which is worked in America under the name of *pacos*, has some analogy with this substance; but iron ore is in general so plentifully diffused on the surface of the soil that its presence can be regarded as only a remote indication relative to other mineral substances, except in the case of clay-ironstone with coal. The *gossans* of Cornwall, occurring in the upper portions of lodes, are analogous formations to the *eiserne Hut* of the German miners.

Mineral veins are subject to derangements in their course, which are called shifts or *faults*. Thus, when a transverse vein throws out, or intercepts, a longitudinal one, we must commonly look for the rejected vein on the side of the obtuse angle which the direction of the latter makes with that of the former. When a bed of ore is deranged by a fault, we must observe whether the slip of the strata be upwards or downwards; for, in either circumstance, it is only by pursuing the direction of the fault that we can recover the ore; in the former case by mounting, in the latter by descending beyond the dislocation.

When two veins intersect each other, the direction of the *offcast* is a subject of interest both to the miner and the geologist. In Saxony it is considered as a general fact that the portion thrown out is always upon the side of the obtuse angle, a circumstance which holds also in Cornwall; and the more obtuse the angle, the outthrow is the more considerable. A vein may be thrown out on meeting another vein, in a line which approaches either towards its inclination or its direction. The Cornish miners use two different terms to denote these two modes of rejection; for the first case they say the vein is *heaved*, for the second it is *started*.


1447

The great copper lode of Carharack (*d*, *fig.* 1447), in the parish of Gwennap, is an instructive example of intersection. The thickness of this vein is 8 feet; its direction is nearly east and west, and it dips towards the north at an inclination of 2 feet per fathom; its upper part being in the *killas* (a greenish clay-slate), its lower part in the granite. The lode has suffered two intersections: the first produced by meeting the vein *h*, called *Stevens's fluckan*, which runs from north-west to south-east, and which throws the lode several fathoms out; the second vein is produced by another vein, *i*, almost at right angles with the first, and which occasions another out-throw of 20 fathoms to the right side. The fall of the vein occurs therefore in the one case to the right, and in the other to the left; but in both it is towards the side of the obtuse angle. This distribution is very singular, for one part of the vein appears to have mounted while the other has descended. N, S, denotes north and south. *d* is the copper lode running east and west; *h*, *i*, are systems of clay-slate veins called *fluckans*; the line over S represents the downthrow, and *d'* the up-throw.

There is a great want of exactness of expression in the terms used to describe the phenomena of dislocations. The foregoing paragraphs are strictly according to the technical language of the miner, who usually regards the cross-courses, here called *fluckans*, as being the *cause* of the alteration in the mineral veins, whereas they are themselves merely the effect of the general movement of the rock masses. The singularity alluded to disappears if the woodcut be regarded as a cross-section representing the result of two distinct movements in a direction from the observer. See FAULTS.

In different districts in this country the terms used to distinguish mineral veins vary considerably. The following terms prevail in Derbyshire and the north of England.

Lodes or mineral veins are usually distinguished by the miners of these districts into at least four species: 1. The rake vein; 2. The pipe vein; 3. The flat or dilated vein; and 4. The interlaced mass (*Stock-werke*), indicating the union of a multitude of small veins mixed in every possible direction with each other, and with the rock.

1. The *rake* vein is a mineral fissure; and is the form best known among practical miners. It commonly runs in a straight line, beginning at the superfices of the strata, and cutting them downwards, generally further than can be reached. This vein sometimes stands quite perpendicular; but it more usually inclines or hangs over at a greater or smaller angle, or slope, which is called by the miners the *hade* or *hading* of the vein. The line of direction in which the fissure runs, is called the *bearing of the vein*.

2. The *pipe* vein resembles in many respects a huge irregular cavern, pushing forward into the body of the earth in a sloping direction, under various inclinations, from an angle of a few degrees to the horizon, to a dip of 45°, or more. The pipe does not in general cut the strata across like the rake vein, but insinuates itself between them; so that if the plane of the strata be nearly horizontal, the bearing of the pipe vein will be conformable; but if the strata stand up at a high angle, the pipe shoots down nearly headlong like a shaft. Some pipes are very wide and high, others are very low and narrow, sometimes not larger than a common mine or drift.

3. The *flat* or *dilated* vein, is a space or opening between two strata or beds of stone, the one of which lies above, and the other below this vein, like a stratum of coal between its roof and pavement: so that the vein and the strata are placed in the same plane of inclination. These veins are subject, like coal, to be interrupted, broken, and thrown up or down by slips, dykes, or other interruptions of the regular strata. In the case of a metallic vein, a slip often increases the chance of finding more treasure. Such veins do not preserve the parallelism of their beds, characteristic of coal seams; but vary excessively in thickness within a moderate space. Flat veins occur frequently in limestone, either in a horizontal or declining direction. The flat or strata-veins open and close, as the rake veins also do.

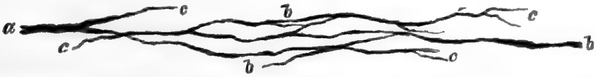
4. The interlaced mass has been already defined. The interlaced strings are more frequent in primitive formations, than in the others.

To these may be added the *accumulated* vein, or irregular mass (*Butzenwerke*), a grave deposit placed without any order in the bosom of the rocks, apparently filling up cavernous spaces.

In Cornwall and Devonshire, where different conditions prevail, other terms are employed.

The *lode*, or mineral vein, is, as in the former instances, a great line of dislocation, accompanied by minor lines of fracture. Of these Sir H. De la Beche says, 'It could scarcely be supposed that the great lines of fracture would be unaccompanied by smaller dislocations, running from them in various directions according to modifying resistances, which would depend upon the kinds of rock traversed by the great fractures, the direction in which they are carried through them as regards the bearing of their strata should they be stratified, and other obvious causes.' The great fractures would often also tend to split in various directions, and reunite into main lines, as in the annexed sketch (*fig.* 1448), in which *a b* represents the line of principal fracture, splitting at *b b* from local causes, and uniting, both towards *a* and *b*, minor cracks running into the adjoining rocks at *c, c, c, c*. These are known as *side-lodes, strings, feeders,* and *branches.*

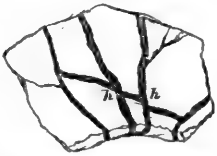
1448



These *strings* are sometimes very curiously developed, and illustrate the peculiar force of crystalline action, and all the phenomena of *heaves* and faults. The following figure (1449) furnishes a good illustration.

It represents a specimen of strings of oxide of tin in slate from St. Agnes, Cornwall, *h h* illustrating the *heaves* alluded to. Sir Henry de la Beche is disposed to refer these to the fact of oxide of tin recementing fractured masses of slate. We think we have sufficient evidence for referring the action to the crystallogenic force enlarging a fissure, or small crack, producing those lateral cracks, which again, by the operation of the same force, dislocate or heave the original fissure.

1449

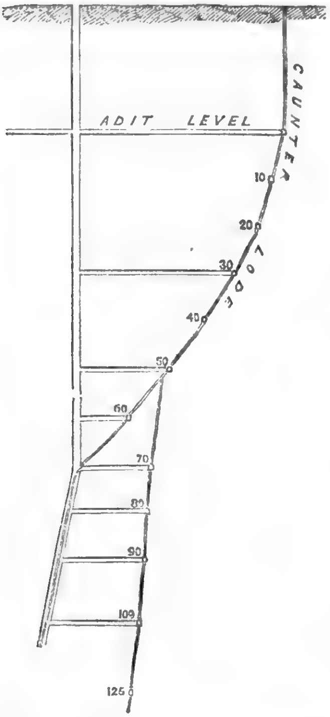


In these lodes we find peculiar mechanical arrangements, which are known by various names; a lode is said to be *comby* when we have the crystals of quartz or other mineral dovetailing, as it were, with the metalliferous masses. *Bunches* are isolated masses of ore found in the lode surrounded by earthy minerals. The upper part of a lode is known as its *back*, and the accumulations of ferruginous matter which very commonly occur in the *backs* and near the surface are known as *gossans*. These are to the experienced miner important guides as indicating the characters of the lode at a greater depth. *The country* signifies, with the Cornish miner, the rock through which the mineral vein runs, and accordingly as he is pleased with the indications he speaks of its being *kindly* or the contrary. The softer rocks, whether of clay-slate or granite, are spoken of as *plumb*, and a *plumb granite*, or *elvan*, is greatly preferred to the harder varieties, and spoken of as being more kindly.

The rock forming the sides of a lode are known as its *walls* or *cheeks*. The latter term we have heard of late years in Cornwall, but we believe it to be imported by miners who have worked in the north of England. As all mineral veins incline more or less, the sides are spoken of as the upper and under walls, the upper being usually termed the *hanging wall*, and the lower the *foot-wall.*

The following woodcuts, *figs.* 1450, 1451, will serve to assist the reader in understanding the peculiarities of mining operations in our metalliferous mines. In *fig.* 1451, which is a section of one of the lead mines of Cardiganshire, the shafts, which have been sunk on the lode are shown, at varied angles from the vertical and the several horizontal levels. In this instance these *levels* or *galleries* have been worked at irregular distances. In Cornwall they are usually ten fathoms apart. The smaller shafts connecting the levels one with the other are called *winzes.* They serve for exploring the lode, or for purposes of ventilation, when the excavations are going forward. When these smaller connected shafts are worked upwards, as they sometimes are, they are called '*risings*,' and the miner is said to be working on the '*rise.*' In this woodcut the lightest shading is to indicate a portion of this particular mine which was worked out by the Romans. The darker shaded masses indicate portions of the lode which have been very productive of metalliferous matter, and which have consequently been removed. The term *counter* or *caunter lode* is given to such lodes as dip at a considerable angle with the direction of the other lodes in its vicinity. Such a lode is shown, *fig.* 1450, which is, however, inserted principally to explain that where the 'underlie' of the lode is great, a vertical shaft is sunk at some distance from it on the surface, so as to 'cut' (intersect) the lode at some depth, in this instance at 70 fathoms below the adit-level. As the inclination of the lode then alters, the shaft is continued on the lodes. Another fissure or lode, sometimes called a '*dropper*,' is seen to take nearly a vertical direction from the 50-fathom level, and from the shafts levels are driven into this lode, at about every 10 fathoms.

1450



1451

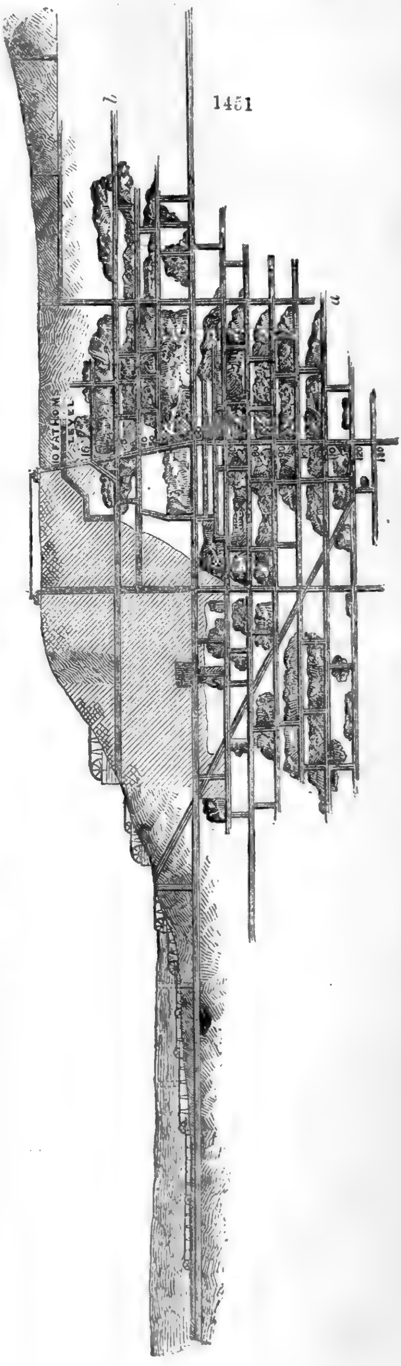
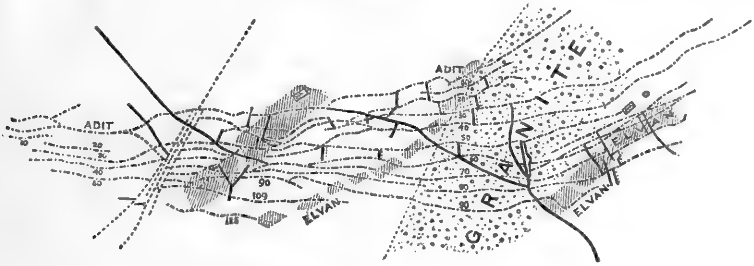


Fig. 1452 represents in plan the underground workings of a Cornish mine. Those who are not familiar with mining are requested to suppose that the earth is transparent so as to enable us to see the *levels* worked at various depths, from the *adit-level*—through which the water pumped from the mine is discharged —to the 125-fathom level below it. These levels are numbered in the plan. They are not worked immediately under one another; but, as the lode inclines, in the same way as is shown in the *Caunter lode* (*fig.* 1450), they follow in position this *underlie* of the lode. The dark lines and the dotted lines crossing the numbered lodes, are workings upon lodes, running in a contrary direction to the lode principally shown. This plan shows the junction of the granite with the killas or clay-slate of Cornwall, and the occurrence of *elvan* courses is shown at the different levels. By studying the plan, with the horizontal and transverse section, the operations of metalliferous mining will be understood.

1452



Of Mining in particular.

The mode of working mines is two-fold; by *open excavations*, and *subterranean* exploitation.

Workings in the open air present few difficulties, and occasion little expense, unless when pushed to a great depth. They are always preferred for working deposits little distant from the surface; where, in fact, other methods cannot be resorted to, if the substance to be raised be covered with incoherent matters. The only rules to be observed are, to arrange the workings in terraces, so as to facilitate the cutting down of the earth; to transport the ores and the rubbish to their destination at the least possible expense: and to guard against the crumbling down of the sides. With the latter view, they ought to have a suitable slope, or to be propped by timbers whenever they are not quite solid.

Open workings are employed for valuable clays, sands, as also for the alluvial soils of diamonds, gold, and oxide of tin, iron ores, &c., limestones, gypsums, building stones, roofing slates, masses of rock salt in some situations, and certain deposits of ores, particularly the specular iron of the island of Elba; the masses of stanniferous granite of Geyer, Altenberg, and Seyffen, in the Erzgebirge, a chain of mountains between Saxony and Bohemia; the thick veins or masses of magnetic oxide of iron of Nordmarch, Dannemora, &c., in Sweden; the mass of cupreous pyrites of Ræraas, near Drontheim, in Norway; several mines of iron, copper, and gold in the Ural mountains. Some of the iron mines near Whitehaven, and Carclase tin mine in Cornwall, may also be quoted.

Subterranean workings may be conveniently divided into five classes, viz.:—

1. Veins, or beds, much inclined to the horizon, varying much in thickness.
2. Beds of slight inclination, or nearly horizontal, the power or thickness of which does not exceed two yards.
3. Beds of great thickness, but slightly inclined.
4. Veins, or beds highly inclined, of great thickness.
5. Masses of considerable magnitude in all their dimensions.

Subterranean mining requires two very distinct classes of workings: the *preparatory*, and those for *extraction*.

The *preparatory* consist in galleries, or in pits (shafts) and levels destined to conduct the miner to the point most proper for attacking the deposit of ore, for tracing it from this point, for preparing chambers of excavation, and for concerting measures with a view to the circulation of air, the discharge of waters, and the transport of the extracted minerals.

If the vein or bed in question be placed in a mountain, and if its direction forms a very obtuse angle with the line of the slope, the miner begins by opening in its side, at the lowest possible level, a gallery (level) of elongation, which serves at once to give issue to the waters, to explore the deposit through a considerable extent, and then to follow it in another direction; but to commence the real mining operations, he pierces either shafts or galleries, according to the slope of the deposit, across the first gallery.

For a stratum but little inclined to the horizon, placed beneath a plain, the first thing is to pierce two vertical shafts, which are usually made to arrive at two points in the same line of slope, and a gallery is driven to unite them. It is, in the first place, for the sake of circulation of air that these two pits are sunk; one of them, which is also destined for the drainage of the waters, should reach the lowest point of the intended workings. If a vein is intersected by transverse ones, the shafts are placed so as to follow, or, at least, to cut through the intersections. When the mineral ores lie in nearly vertical masses, it is right to avoid, as far as possible, sinking pits into their interior. These should rather be perforated at one side of their floor, even at some considerable distance, to avoid all risk of crumbling the ores into a heap of rubbish, and overwhelming the workmen.

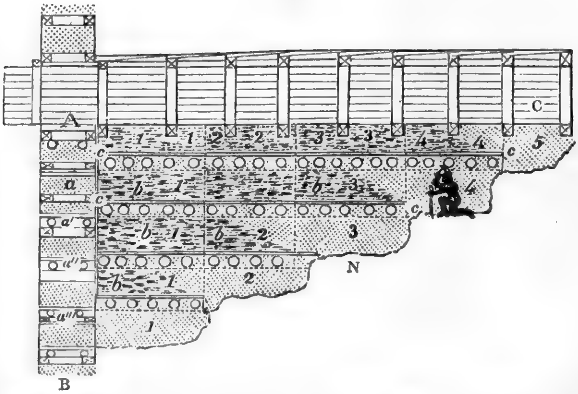
With a vein of moderate width, as soon as the preparatory labours have brought the miners to the point of the vein from which the ulterior workings are to ramify, whenever a circulation of air has been secured, and an outlet to the water and the matters mined, the first object is to divide the mass of ore into large parallelopipeds, by means of oblong galleries, pierced ten fathoms below one another, with pits of communication opened up, 30, 40, or 50 yards asunder, which follow the slope of the vein. These galleries and shafts are usually of the same breadth as the vein, unless when it is very narrow, in which case it is requisite to cut out a portion of the roof or the floor. Such workings serve at once the purposes of mining, by affording a portion of ore, and the complete investigation of the nature and riches of the vein, a certain extent of which is thus prepared before removing the cubical masses. It is proper to advance first of all, in this manner, to the greatest distance from the central point which can be mined with economy, and afterwards to remove the parallelopiped blocks, in working back to that point.

This latter operation may be carried on in two different ways; of which one consists in attacking the ore from above, and another from below. In either case, the excavations are disposed in steps similar to a stair upon their upper or under side. The first is styled a *working* in *direct* or descending steps; and the second a *working* in *reverse*, or ascending steps.

The descriptions given by Dr. Ure relate chiefly to the processes carried forward in the German mines. In very many respects they resemble our own processes of mining; and, for the general information these give to the English reader, Dr. Ure's description has been retained.

1. Suppose, for example, that the post N, *fig.* 1453, included between the horizontal gallery A C and the shaft A B, is to be excavated by direct steps, a workman stationed upon a scaffold at the point *a*, which forms the angle between the shaft and the elongated drift, attacks the rock in front of him and beneath his feet. Whenever he has cut out a parallelopiped (a rectangular mass), of from four to six yards broad, and two yards high, a second miner is set to work upon a scaffold at *a′*, two yards beneath the first, who, in like manner, excavates the rock under his feet and before him. As soon as the second miner has removed a post of four or six yards in width, by two in height, a third begins upon a scaffold at *a″* to work out a third step. Thus, as many workmen are employed as there are steps to be made between the two oblong horizontal galleries which extend above and below the mass to be excavated; and since they all proceed simultaneously, they continue working in similar positions, in floors, over each other, as upon a stair with very long wide steps. As they advance, the miners construct before them wooden floors *c c c c*, for the purpose of supporting the rubbish which each workman extracts from his own step. This floor, which should be very solid, serves also for wheeling out his barrow filled with ore. The round billets which support the planks sustain the roof or the wall of the mineral vein or bed

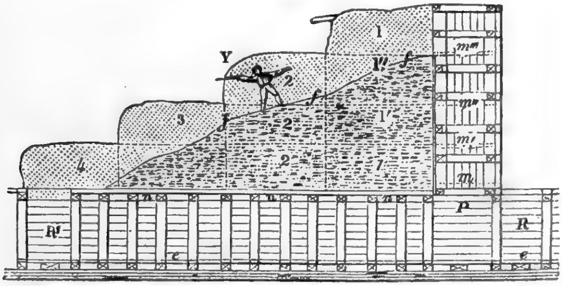
1453



under operation. If the rubbish be very considerable, as is commonly the case, the floor planks are lost. However strongly they may be made, as they cannot be repaired, they sooner or later give way under the enormous pressure of the rubbish; and as all the weight is borne by the roof of the oblong gallery underneath, this must be sufficiently timbered. By this ingenious plan, a great many miners may go to work together upon a vein without mutual interference; as the portions which they detach have always two faces at least free, they are consequently more easily separable, either with gunpowder or with the pick. Should the vein be more than a yard thick, or if its substance be very refractory, two miners are set upon each step. *b b b b* indicate the quadrangular masses that are cut out successively downwards; and 1 1, 2 2, 3 3, forwards; the lines of small circles are the sections of the ends of the billets which support the floors.

2. To attack a mass Y, *fig.* 1454, a scaffold *m*, is erected in one of its terminal pits P, at the level of the ceiling of the gallery R R′, where it terminates below. A miner placed on this scaffold, cuts off at the angle of this mass a parallelopiped 1, from one to two yards high, by six or eight long. When he has advanced thus far, there is placed in the same pit upon another scaffold *m′*, a second miner, who attacks the vein above the roof of the first cutting, and hews down, above the parallelopiped 1, a parallelopiped of the same dimensions 1′, while the first is taking out another, 2, in advance of 1. When the second miner has gone forward 6 or 8 yards, a third is placed also in the same pit. He commences the third step, while the first two miners are pushing forward theirs, and so in succession.

1454



In this mode of working, as well as in the preceding, it is requisite to support the rubbish and the walls of the vein. For the first object, a single floor, *n n n*, may be sufficient, constructed above the lower gallery, substantial enough to bear all the rubbish, as well as the miners. In certain cases, an arched roof may be substituted; and in others, several floors are laid at different heights. The sides of the vein are supported by means of pieces of wood fixed between them perpendicularly to their planes. Sometimes, in the middle of the rubbish, small pits are left at regular distances apart, through which the workmen throw the ore coarsely picked, down into the lower gallery. The rubbish occasionally forms a slope *f f f*, so high that miners placed upon it can work conveniently. When the rich portions are so abundant as to leave too little rubbish to make such a sloping platform, the miners plant themselves upon moveable floors, which they carry forward along with the excavations.

These two modes of working in the *step-form* have peculiar advantages and disadvantages; and each is preferred to the other, according to circumstances.

In the *descending workings*, or in *direct steps*, *fig.* 1453, the miner is placed on the very mass or substance of the vein; he works commodiously before him; he is not exposed to the splinters which may fly off from the roof; but by this plan he is obliged to employ a great deal of timber to sustain the rubbish; and the wood is fixed for ever

In the *ascending workings*, or in *reversed steps*, *fig.* 1454, the miner is compelled to work in the re-entering angle formed between the roof and the front wall of his excavation, a posture sometimes oppressive; but the weight of the ore conspires with his efforts to make it fall. He employs less timber than in the *workings* with *direct steps*. The *sorting* of the ore is more difficult than in the *descending working*, because the rich ore is sometimes confounded with the heap of rubbish on which it falls.

When seams of diluvium or gravel-mud occur on one of the sides of the vein or on both, they render the quarrying of the ore more easy, by affording the means of uncovering the mass to be cut down, upon an additional face.

Should the vein be very narrow, it is necessary to remove a portion of the sterile rock which encloses it, in order to give the work a sufficient width to enable the miner to advance. If, in this case, the vein be quite distinct from the rock, the labour may be facilitated, as well as the separation of the ore, by disengaging the vein, on one of its faces through a certain extent, the rock being attacked separately. This operation is called *stripping the vein.* When it is thus uncovered, a shot of gunpowder is sufficient to detach a great mass of it, unmixed with sterile stones.

By the methods now described, only those parallelopipeds are cut out, either in whole or in part, which present indications of richness adequate to yield a prospect of benefit. In other cases, it is enough to follow out the threads of ore which occur, by workings made in their direction.

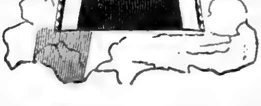
The miner, in searching within the crust of the earth for the riches which it conceals, is exposed to many dangers. The rocks amidst which he digs are seldom or never entire, but are almost always traversed by clefts in various directions, so that impending fragments threaten to fall and crush him at every instant. He is even obliged at times to cut through rotten friable rocks or alluvial loams. Fresh atmospheric air follows him with difficulty in the narrow channels which he lays open before him; and the waters which circulate in the subterranean seams and fissures filter incessantly into his excavation, and tend to fill it. Let us now take a view of the means he employs to escape from these three classes of dangers.

1. *Of the timbering of excavations.*—The excavations of mines are divisible into three principal species: *shafts, galleries,* and *chambers.* When the width of these excavations is inconsiderable, as is commonly the case with shafts and galleries, their sides can sometimes stand upright of themselves; but more frequently they require to be propped or stayed by billets of wood, or by walls built with bricks or stones; or even by stuffing the space with rubbish. These three kinds of *support* are called *timbering, walling,* and *filling up.*

Timbering is most used. It varies in form for the three species of excavations, according to the solidity of the walls which it is destined to sustain.

In a gallery, for example, it may be sufficient to support merely the roof, by means of joists placed across, bearing at their two ends in the rock; or the roof and the tow walls by means of an upper joist, s, *fig.* 1455, which is then called a *cap* or *cornice beam,* resting on two lateral upright posts or *stanchions, a b,* to which a slight inclination towards each other is given, so that they approach a little at the top, and rest entirely upon the floor. At times, only one of the walls and the roof need support. This case is of frequent occurrence in pipe veins. Pillars are then set up only on one side, and on the other the joists rest in holes of the rock. It may happen that the floor of the gallery shall not be sufficiently firm to afford a sure foundation to the standards; and it may be necessary to make them rest on a horizontal piece called the *sole.* This is timbering with *complete frames.* The upright posts are usually set directly on the sole; but the extremities of the *cap* or ceiling, and the upper ends of the *standards,* are mortised in such a manner that these cannot come nearer, whereby the cap shall possess its whole force of resistance. In friable and shivery rocks there is put behind these beams, both upon the ceiling and the sides, *facing boards,* which are planks placed horizontally, or spars of cleft wood, set so close together as to leave no interval. They are called *fascines* in French. In ordinary ground, the miner puts up these *planks* in proportion as he goes forwards; but in a loose soil, such as sand or gravel, he must mount them a little in advance. He then drives into the mass behind the wooden framework thick but sharp-pointed planks or stakes, and which, in fact, form the sides of the cavity, which he proceeds to excavate. Their one extremity is thus supported by the earth in which it is thrust, and their other end by the last framing. Whenever the miner gets sufficiently on, he sustains the walls by a new frame. The size of the timber, as well as the distance between the frames or *stanchions,* depends on the degree of pressure to be resisted.

1455



When a gallery is to serve at once for several distinct purposes, a greater height is given to it; and a flooring is laid on it at a certain level. If, for example, a gallery is to be employed, both for the transport of the ores and the discharge of the waters, a floor, *e e, fig.* 1454 is constructed above the bottom, over which the carriages are wheeled, and under which the waters are discharged.

The timbering of shafts varies in form, as well as that of galleries, according to the nature and the locality of the ground which they traverse, and the purposes which they are meant to serve. The shafts intended to be stayed with timber are usually square or rectangular, because this form, in itself more convenient for the miner, renders the execution of the timbering more easy. The woodwork consists generally of rectangular frames, the spars of which are about eight inches in diameter, and placed at a distance asunder of from a yard to a yard and a half. The spars are never placed in contact, except when the pressure of the earth and the water is very great. The pieces composing the frames are commonly united by a half-check, and the longer of the two pieces extends often beyond the angles, to be rested in the rock. Whether the shaft is vertical or inclined, the framework is always placed so that its plane may be perpendicular to the axis of the pit. It happens sometimes in inclined shafts that there are only two sides, or even a single one, which need to be propped. These are stayed by means of cross beams, which rest at their two ends in the rock. When the frames do not touch one another strong planks or stakes are fastened behind them to sustain the ground. To these planks the frames are firmly connected, so that they cannot slide. In this case the whole timbering will be supported, when the lower frame is solidly fixed, or when the pieces from above pass by its angles to be abutted upon the ground.

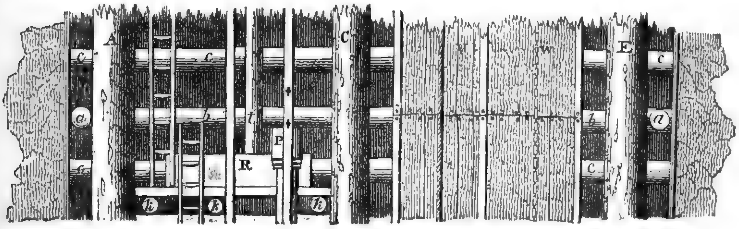
In the large rectangular shafts, which serve at once for extracting the ores, for the discharge of the waters, and the descent of the workmen, the spaces destined for these several purposes are in general separated by partitions, which also serve to increase the strength of the timberings, by acting as buttresses to the planks in the long sides of the framework. Occasionally a partition separates the ascending from the descending basket, to prevent their jostling. Lastly, particular passages are left for ventilation.

As it is desirable that the wood shall retain its whole force, only those pieces are squared which absolutely require it. The spars of the frames in shafts and galleries are deprived merely of their bark, which, by holding moisture, would accelerate the decomposition of the wood. The alburnum of oak is also removed.

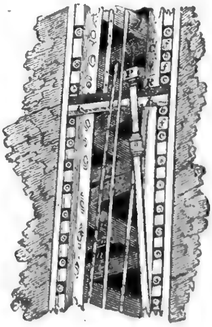
Resinous woods, like the pine, last much shorter than the oak, the beech, and the cherry-tree; though the larch is used with advantage. The oak has been known to last upwards of 40 years; while the resinous woods decay frequently in 10. The fresher the air in mines, the more durable is the timbering.

The *figs.* 1456, 1457 represent two vertical sections of a shaft, the one at right angles to the other, with the view of showing the mode of sustaining the walls of the excavation by timbering. It is copied from an actual mine in the Hartz. There we may observe the spaces allotted to the descent of the miners by ladders, to the drainage of the waters by pumps P, and rods *t*, and to the extraction of the mineral substances by baskets. *a*, *b*, *c*, *f*, *h*, *k*, are various cross timbers; A, C, E, upright do.; R, pump cistern; V, W, corve-ways. The shafts here shown, are excavated in the line of the vein itself,—the rock enclosing it being seen in the second figure.

1456



1457



In a great many mines it is found advantageous to support the excavations by brick or stone buildings, constructed either with or without mortar. These constructions are often more costly than wooden ones, but they last much longer, and need fewer repairs. They are employed instead of timberings, to support the walls and roof of galleries, to line the sides of shafts, and to bear up the roofs of excavations.

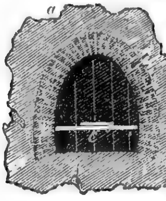
Sometimes the two sides of a gallery are lined with vertical walls, and its roof is supported by an ogee vault, or an arch. If the sides of the mine are solid, a simple arch is sufficient to sustain the roof, and at other times the whole surface of a gallery is formed of a single elliptic vault, the great axis of which is vertical; and the bottom is surmounted by a wooden plank, under which the waters run off: see *fig.* 1458.

Walled shafts also are sometimes constructed in a circular or elliptic form, which is better adapted to resist the pressure of the earth and waters. Rectangular shafts of all dimensions, however, are frequently walled.

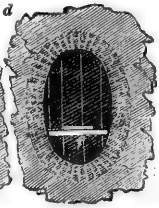
The sides of an excavation may also be supported by filling it completely with rubbish. Whenever the sides need to be supported for some time without the necessity of passing along them, it is often more economical to stuff them up with rubbish, than to keep up their supports. In the territory of Liège, for example, there have been shafts thus filled up for several centuries; and which are found to be quite entire when they are emptied. The rubbish is also useful for forming roads among steep strata, for closing air-holes, and forming canals of ventilation.

Figs. 1458, 1459, 1460, represent the principal kinds of mason-work employed in the galleries and shafts of mines. *Fig.* 1461 exhibits the walling in of the cage of an overshot water-wheel, as mounted within a mine. Before beginning to build, an excavation large enough must be made in the gallery to leave a space three feet and a half high for the workman to stand in, after the brick-work is completed. Between the two opposite sides, cross beams of wood must be fixed at certain distances as chords of the vault, over which the rock must be hollowed out to receive the arch-stones, and the centring must then be placed covered with deals to receive the *voussoirs*, beginning at the flanks and ending with the keystone. When the vault is finished through a certain extent, the interval between the arch and the rock must be rammed full of rubbish, leaving passages if necessary through it and the arch, for currents of water.

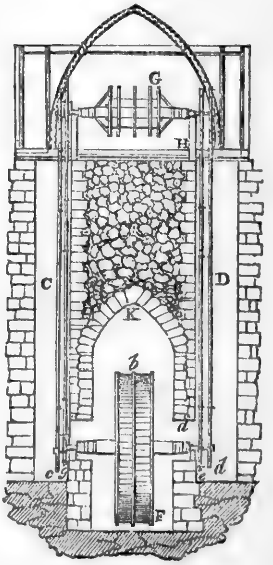
1459

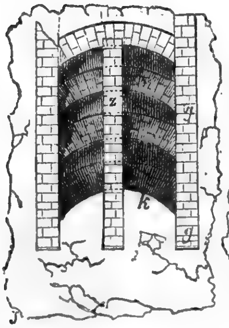


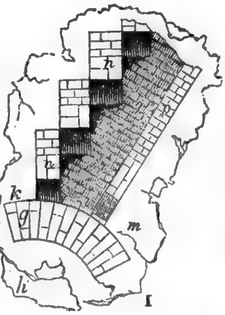
1458



1461







In walling galleries, attention must be paid to the direction of the pressure, and to build vertically or with a slope accordingly. Should the pressure be equal in all directions, a closed vault, like *fig.* 1458, should be formed. For walls not far from the vertical, salient or buttressed arches are employed, as shown in *fig.* 1460, called in German *überspringende Bogen*; for other cases, twin-arches are preferred, with an upright wall between.

Fig. 1459 is a transverse section of a walled drain-gallery, from the grand gallery of the Hartz; see also *fig.* 1461. *a* is the rock which needs to be supported only at the sides and top; *b*, the masonwork, a curve formed of the three circular arcs upon one level; *c*, the floor for the water-course. *Fig.* 1458 is a cross-section of a walled gallery, as at Schneeberg, Rothenburg, Idria, &c.; *d* is the rock, which is not solid either at the flanks, roof, or floor; *e*, the elliptic masonwork; *f*, the wooden floor for the waggons, which is sometimes, however, arched in brick to allow of a watercourse beneath it.

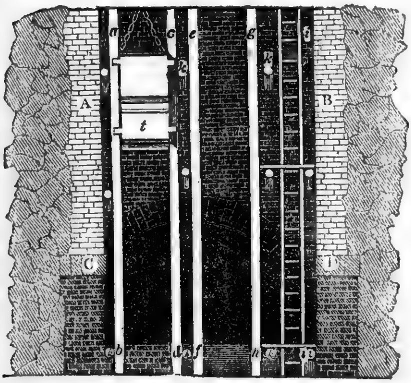
Fig. 1460 shows two vertical projections of a portion of a walled shaft with buttresses, as built at the mine *Vater Abraham*, near Marienberg. J is a section in the direction of the vein *g h*, to show the roof of the shaft. I, a section exhibiting the slope of the vein *g h*, into which the shaft is sunk; *m* is the wall of the vein; *k* is the roof of the same vein; *n*, buttresses resting upon the flanks of the shaft; *g*, great arcs on which the buttresses bear; *y*, vertical masonwork; *z*, a wall which divides the shaft into two compartments, of which the larger *p* is that for extracting the ore, and the smaller for the draining and for the descent of the miners.

Fig. 1461. C D is the shaft in which the vertical crank-rods *c*, *g*, *e*, *d*, move up and down. F, is a double hydraulic wheel, which can be stopped at pleasure by a brake mounted upon the machine of extraction. G, is the drum of the gig or whim for raising the *corves* or tubs (*tonnes*); H, is the level of the ground, with the carpentry which supports the whim and its roof. K, is the keystone of the *ogee* arch which covers the water-wheel; *a*, is the opening or window, traversed by the extremity of the driving shaft, upon each side of the water-wheel, through which a workman may enter to adjust or repair it; *b*, line of conduits for the streams of water which fall upon the hydraulic wheel; *c*, *g*, double crank with rods, whose motion is taken off the left side of the wheel; *e*, *d*, the same upon the right side. The distance from H to F is about 22 yards.

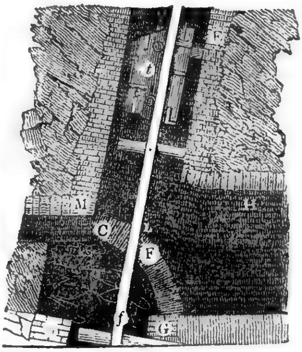
Figs. 1462, 1463, present two vertical sections of the shaft of a mine walled, like the roof of a cavern, communicating with the galleries of the roof and the wall of the vein, and well arranged for both the extraction of the ore, and the descent of the miners. The vertical partition of the shaft for separating the passage for the corves or tubs from the ladders is omitted in the figure, for the sake of clearness.

In *fig.* 1462, A B are the side-walls supported upon the buttresses C and D; in *fig.* 1463, E is the masonry of the wall, borne upon the arch F at the entrance to a gallery, the continuation being at G, which is sustained by a similar arch built lower.

1462



1463



L, is the vault arch of the roof, supported upon another vault M, which presents a double curvature, at the entrance of a gallery; at H is the continuation of the arch or vault L, which underneath is supported in like manner at the entrance of a lower gallery.

a, *b*, *c*, *d*, *fig.* 1462, are small upright guide-bars or rods for one of the corves, or kibbles.

e, *f*, *g*, *h*, are similar guide-bars for the other corf.

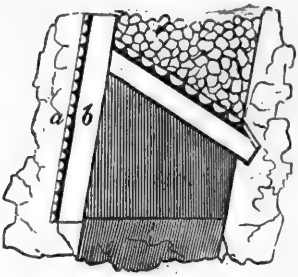
i i, are cross-bars of wood, which support the stays of the ladders of descent.

k k, are also cross-bars by which the guide-rods are secured.

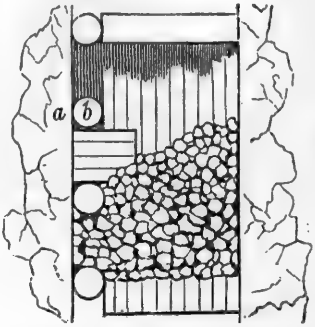
t, a *corf*, or extraction-kibble, furnished with friction rollers; the other corf is supposed to be drawn up to a higher level, in the other vertical passage.

Figs. 1464, 1465 represent in a vertical section the mode of timbering the galleries of the silver and lead mines at Andreasberg in the Hartz. *Fig.* 1464 shows the plan viewed from above. Upon the roof of the timbering, the workman throws the waste rubbish, and in the empty space below, which is shaded black, he transports in his waggons or wheel-barrows the ores towards the mouth of the mine. *Fig.* 1465 is the cross-section of the gallery. In the two figures, *a* represents the rock, and *b* the timbering; round which there is a garniture of small spars or lathes for the purpose of drainage and ventilation, with the view of promoting the durability of the wood-work.

1464



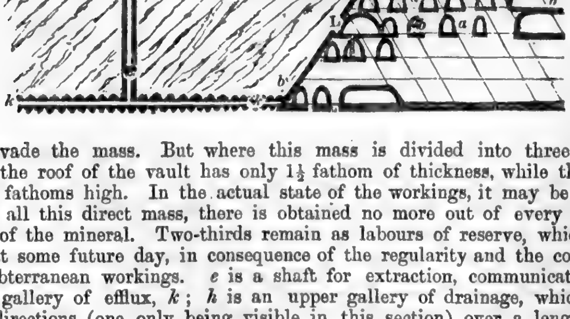
465



The working of minerals by the *mass* is well exemplified a few leagues to the north of Siegen, near Müsen (Rhenish Prussia), in a mine of iron and other metals, called Stahlberg, which forms the main wealth of the country. The plan of working is termed *the excavation of a direct or transverse mass.* It shows in its upper part the danger of bad mining, and in its inferior portion, the regular workings, by whose means art has eventually prevented the destruction of a precious mineral deposit.

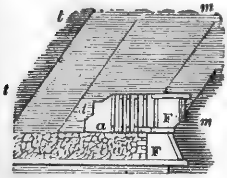
Fig. 1466 is a vertical section of the bed of ore, which is a *direct* mass of spathose iron, contained in Devonian clay-slate. *a, a, a,* are pillars of the sparry ore reserved to support the successive stages or floors, which are numbered 1, 2, 3, &c. *b, b, b,* are excavations worked in the ore; which exhibit at the present day several floors of arches, of greater or less magnitude, according to the localities. It may be remarked, that where the metallic deposit forms one entire mass, rich in spathose iron ore of good quality, there is generally given to the vaults a height of 3 fathoms; leaving a thickness over the roof of 2 fathoms, on account of the numerous fissures which pervade the mass. But where this mass is divided into three principal branches, the roof of the vault has only 1½ fathom of thickness, while the excavation is 3½ fathoms high. In the actual state of the workings, it may be estimated that from all this direct mass, there is obtained no more out of every floor than one-third of the mineral. Two-thirds remain as labours of reserve, which may be resumed at some future day, in consequence of the regularity and the continuation of the subterranean workings. *e* is a shaft for extraction, communicating below with the gallery of efflux, *k*; *h* is an upper gallery of drainage, which runs in different directions (one only being visible in this section) over a length of 400 fathoms; the lower gallery, *k*, runs 646 fathoms in a straight line; *m m,* represents the mass of sparry iron.

1466



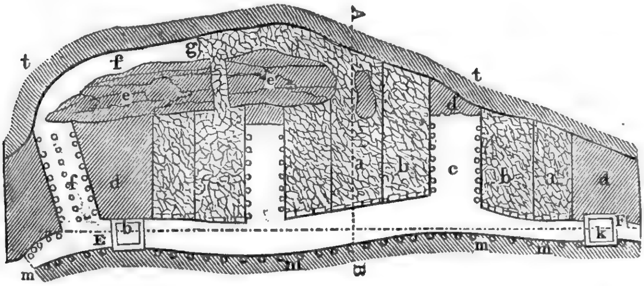
Figs. 1467, 1468, 1469, represent the cross system of mining, which consists in forming galleries through a mineral deposit, from its wall or floor towards its roof, and not, as usual, in the direction of its length. This mode was contrived towards the middle of the 18th century, for working the very thick veins of the Schemnitz mine in Hungary; and it is now employed with advantage in many places, particularly at Idria in Carniola. In the two sections, *figs.* 1467, 1469, as well as in the ground-plan, *fig.* 1468, the wall is denoted by *m m*, and the roof by *t t*. A first gallery of prolongation, E F, *fig.* 1468, being formed to the wall, transverse cuts, *a a*, are next established at right angles to this gallery, so that between every two there may be room enough to place three others, *b, c, b*, *fig.* 1468. From each of the cuts, *a*, ore is procured by advancing with the help of timbering, till the roof, *t*, be reached. When this is done, these first cuts, *a*, are filled up with rubbish, laid upon pieces of timber with which the ground is covered, so that if, eventually, it should be wished to mine underneath, no downfall of detritus is to be feared. These heaps of rubbish rise only to within a few inches of the top of the cuts, *a*, in order that the working of the upper story may be easier, the bed of ore being there already laid open upon its lower face.

1467



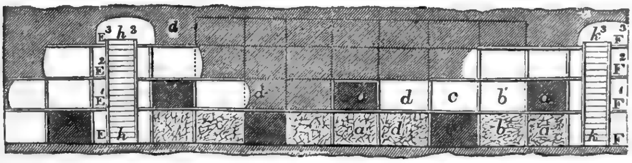
In proportion as the cuts, *a*, of the first story, E F, are thus filled up, the greater part of the timbering is withdrawn, and made use of elsewhere. The intermediate cuts, *b, c, b*, are next mined in like manner, either beginning with the cuts *c*, or the cuts *b*, according to the localities. From *fig.* 1468 it appears that the working may be so arranged that, in case of necessity, there may be always between two cuts in activity the distance of three cuts, either not made, or filled up with rubbish. Hence, all the portion of the bed of ore may be removed which corresponds to a first story, E F, *fig.* 1469, and this portion is replaced by rubbish.

1468



The exploration of the upper stories E$'$ F$'$, E^2 F^2, E^3 F^3, is now prepared in a similar manner; with which view shafts $h\ h^3$, $k\ k^3$, are formed from below upwards in the wall, *m*, of the deposit, and from these shafts oblong galleries proceed, established successively on a level with the stories thus raised over one another. See *fig.* 1469.

1469



The following objects may be specified in the figures:—

a a, the first cuts filled up with rubbish, upon the first story E F, *fig.* 1468.
b b, other cuts subsequently filled up, upon the same story.
c, the cut actually working.
d, the front of the cut, or place of actual excavation of the mineral deposit.
e, masses of the barren rock, reserved in the cutting, for pillars of safety.

f, galleries, by means of which the workmen may turn round the mass *e*, in order to form in the roof, *t*, an excavation in the direction of the deposit.

g, rubbish behind the mass *e*.

h h, two shafts leading from the first story, E F, to the upper stories of the workings, as already stated.

m, the wall, and *t* the roof, of the mineral-bed.

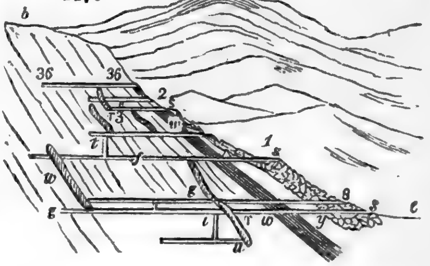
In the second story, E′ F′, the gallery of prolongation, F′, *figs.* 1467, 1469, is not entirely perforated; but it is further advanced than that of the third story, which, in its turn, is more than the gallery of the fourth.

From this arrangement there is produced upon *fig.* 1469 the general aspect of a working by reversed steps.

Whenever the workings of the cuts, *c*, in the first story are finished, those of the second, *a′ a′*, may be begun in the second; and thus, by mounting from story to story, the whole deposit of ore may be taken out and replaced with rubbish. One great advantage of this method is, that nothing is lost; but it is not the only one. The facilities offered by the system of *cross-workings* for disposing of the rubbish, most frequently a nuisance to the miner, and expensive to get rid of, the solidity which it procures by the banking up, the consequent economy of timbering, and saving of expense in the excavation of the rock, reckoning from the second story, are so many important circumstances which recommend this mode of mining. Sometimes, indeed, rubbish may be wanted to fill up, but this may always be procured by a few accessory perforations; it being easy to establish in the vicinity of the workings a vast excavation in the form of a vault, or kind of subterraneous quarry, which may be allowed to fall in, with proper precautions, and where rubbish will thus accumulate in a short time, at little cost.

Fig. 1470 represents a section of the celebrated lead mines of Bleiberg in Carinthia, not far from Villach.

1470



b, c, is the ridge of the mountains of compact limestone, in whose bosom the workings are carried on.

e, is the metalliferous valley, running from east to west, between the two parallel valleys of the Gail and the Drave, but at a level considerably above the waters of these rivers.

f, g, is the direction of a great many vertical beds of metalliferous limestone.

On considering the direction and dip of the marly schist and metalliferous limestone, in the space *w w*, to the west of the line 1, *s*, it would appear that a great portion of this system of mountains has suffered a slip between 1, *s*, and a parallel one towards the east; whereby, probably, that vertical position of the strata has been produced which exists through a considerable extent. The metalliferous limestone is covered to a certain thickness with a marly schist, and other more recent rocks. It is in this schist that the 'fire-marble,' known under the name of the *lumachella of Bleiberg*, is quarried. This appears to be of Liassic age.

The galena occurs at the bottom of this rock in flattened masses, or blocks of a considerable volume, which are not separated from the rest of the calcareous beds by any seam. It is accompanied by zinc ore (*calamine*), especially in the upper parts of the mountain.

Several of the workable masses are indicated by *r*, r^3; each presents itself as a solid analogous to a very elongated ellipse, whose axis dips, not according to the inclination of the surrounding rock, but to an oblique or intermediate line between this inclination and the direction of the beds of limestone; as shown by *r w*, *r′ w′*.

The faults, called *kluft* (*rent*), at Bleiberg are visible on the surface of the ground. Experienced miners have remarked that the rich masses occur more frequently in the direction of these faults than elsewhere.

It is in general by galleries cut horizontally in the body of the mountain, and at different levels, *s g*, *s f*, that the miner advances towards the masses of ore *r*, r^3. Many of these galleries are 500 fathoms long before they reach a workable mass. The several galleries are placed in communication by a few shafts, such as *t*; but few of these are sunk deeper than the level of the valley, *e*.

The total length of the mines of Bleiberg is about 10,000 yards, parallel to the valley *e*; in which space there are 500 concessions granted by the Government to various individuals or joint-stock companies, either by themselves, or associated with the Government.

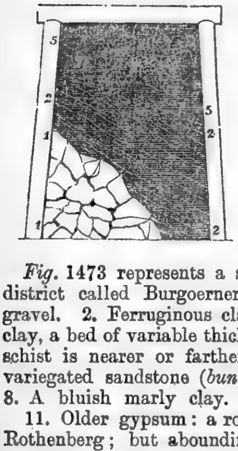
The metalliferous valley contains 5,000 inhabitants, all deriving subsistence from the mines; 300 of whom are occupied in the government works.

Each concession has a number and a name: as Antoni, Christoph, Matthæus, Oswaldi, 2, 8, 36, &c.

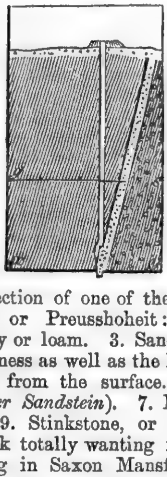
Fig. 1471 is a section of the quicksilver mine of Idria. 1, is the grey limestone; 2, is a blackish slate; 5, is a greyish slate. Immediately above these transition rocks lies the bed containing the ores, called *Corallenerz*, which consist of an intimate mixture of sulphuret of mercury and argillaceous limestone; in which four men can cut out in a month 2½ toises cube of rock.

Fig. 1472 represents a section of part of one of the copper mines of Mansfeld; containing the cellular limestone, called *Rauchwacke*, always with the magnesian limestone, called *Zechstein*; the cupreous schist, or *Kupferschiefer*; the wall of greyish-white sandstone, called the *weisse Liegende*; and the wall of red sandstone, or the *rothe Liegende*. The thin dotted stratum at top is vegetable mould; the large dotted portion to the right of the figure is oolite; the vein at its side is sand; next is *Rauchwacke*; and lastly, the main body of fetid limestone, or *Stinkstein*.

1471



1472



1473

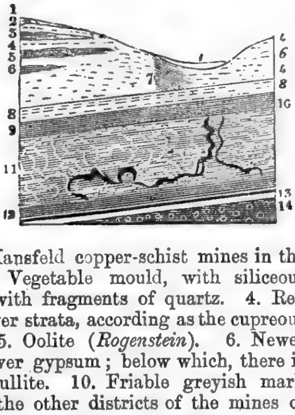


Fig. 1473 represents a section of one of the Mansfeld copper-schist mines in the district called Burgoerner, or Preusshoheit: 1. Vegetable mould, with siliceous gravel. 2. Ferruginous clay or loam. 3. Sand, with fragments of quartz. 4. Red clay, a bed of variable thickness as well as the lower strata, according as the cupreous schist is nearer or farther from the surface. 5. Oolite (*Rogenstein*). 6. Newer variegated sandstone (*bunter Sandstein*). 7. Newer gypsum; below which, there is 8. A bluish marly clay. 9. Stinkstone, or lucullite. 10. Friable greyish marl.

11. Older gypsum: a rock totally wanting in the other districts of the mines of Rothenberg; but abounding in Saxon Mansfeld, where it includes vast caverns known among the miners by the name of *Schlotten*, as indicated in the figure (1473).

12. The calcareous rock, called *Zechstein*. The lower part of this stratum shows symptoms of the cupriferous schist that lies underneath. It presents three thin bands, differently modified, which the miner distinguishes as he descends by the names of the sterile or rotten (*faüle*) rock; the roof (*Dachklotz*); and the main rock (*oberberg*).

13. Is a bed of cupriferous schist (*Kupferschiefer*), also called the *bitumino-marly* schist, in which may be noted, in going down, but not marked in the figure—

a, the *Lochberg*, a seam 4 inches thick.
b, the *Kammschale*, ¼ of an inch thick.
c, the *Kopfschale*, 1 inch thick.

These seams are not worth smelting; the following, however, are:—

d, the *Schiefer-kopf*, the main copper-schist, 2 inches thick.
e, a layer called *Lochen*, 1 inch thick.

14. The wall of sandstone, resting upon a porphyry.

Fig. 1474 is a section of the mines of Kiegelsdorf in Hessia, presenting—

1. Vegetable mould.

2. Limestone distinctly stratified, frequently of a yellowish colour, called *lagerhafter Kalkstein*.

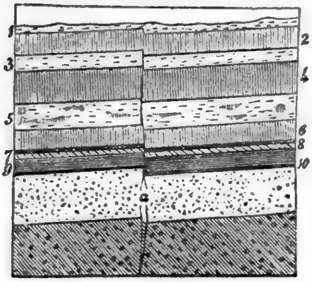
3. Clay, sometimes red, sometime blue, sometimes a mixture of red, blue, and yellow.

4. The cellular limestone (*Rauhkalk*). This rock differs both in nature and position from the rock of the same name at Mansfeld.

5. Clay, usually red, containing veins of white gypsum, and fine crystals of selenite.

6. Massive gypsum of recent formation.

1474



7. Fetid limestone, compact and blackish grey, or cellular and yellowish grey.

8. Pulverulent limestone, with solid fragments interspersed.

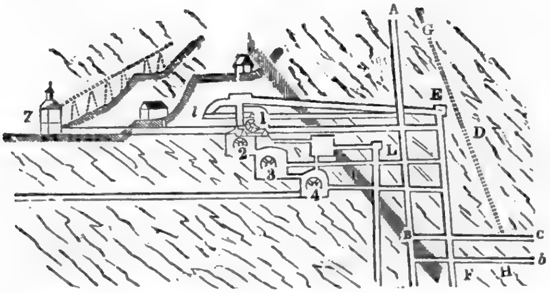
9. Compact marl-limestone, or *Zechstein*, which changes from a brownish colour above to a blackish schist below, as it comes nearer the cupreous schist, which seems to form a part of it.

10. Cupreous schist (*Kuperschiefer*), of which the bottom portion, from 4 to 6 inches thick, is that selected for metallurgic operations. Beneath it is found the usual wall or bed of sandstone. A vein of cobalt ore, *a*, which is rich only in the greyish-white sandstone (*weisse Liegende*), traverses and deranges the beds wherever it comes.

Of working Mines by Fire.—The celebrated mine worked since the 10th century in the mountain called Rammelsberg, in the Hartz, to the south of Goslar, presents a stratified mass of ores, among the beds of the rock which constitute that mountain. The mineral deposit is situated in the earth like an enormous inverted wedge, so that its thickness (power), inconsiderable near the surface of the ground, increases as it descends. At about 100 yards from its outcrop, reckoning in the direction of the slope of the deposit, it is divided into two portions or branches, which are separated from each other, throughout the whole known depth, by a mass of very hard clay-slate, which passes into flinty slate. The substances composing the workable mass are copper and iron pyrites, with sulphuret of lead (galena), accompanied by quartz, carbonate of lime, compact sulphate of baryta, and sometimes grey copper ore, sulphuret of zinc, and arsenical pyrites. The ores of lead and copper contain silver and gold, but in small proportion, particularly as to the last.

A mine so ancient as that of Rammelsberg, and which was formerly divided among several adventurous companies, cannot fail to present a great many shafts and excavations; but, out of the 15 pits, only two are employed for the present workings, namely, those marked A B and E F in *fig.* 1475, by which the whole extraction and drainage are executed. The general system of exploitation by fire, as practised in this mine, consists of the following operations:—

1475



1. An advance is made towards the deposits of ore, successively at different levels, by transverse galleries, which proceed from the shaft of extraction, and terminate at the walls of the stratiform mass.

2. There are formed in the level to be worked large vaults in the heart of the ore, by means of fire, as we shall presently describe.

3. The floor of these vaults is raised up by means of terraces, formed from the rubbish in proportion as the roof is scooped out.

4. The ores detached by the fire from their bed are picked and gathered; sometimes the larger blocks are blasted with gunpowder.

5. Lastly, the ores thus obtained are wheeled towards the shaft of extraction, and turned out to the day.

Let us now see how the excavation by fire is practised; and, in that view, let us consider the state of the workings in the mines of Rammelsberg. We may remark in *fig.* 1475 the regularity of the vaults previously scooped out above the level B C, and the other vaults which are in full activity of operation. It is, therefore, towards the lower levels that the new workings must be directed. For this purpose, the transverse gallery being already completed, there is prepared on the first of these floors a vault of exploitation at *b*, which eventually is to become similar to those of the superior levels. At the same time there is commenced, at the starting-point below it, reached by a small well dug in the line of the mineral deposit, a transverse gallery in the rock, by means of blasting with gunpowder. The rock is also attacked at the starting-point by a similar *cut*, which advances to meet the first perforation. In this way, whenever the vaults of the level C are exhausted of ore, and terraced up with rubbish, those of the level beneath it will be in full activity.

Others will then be prepared at a lower level; and the exploitation may afterwards be driven below this level by pursuing the same plan, by which the actual depth of excavation has been gained.

In workings by fire we must distinguish: 1, the case where it is necessary to open a vault immediately from the floor; 2, the case where, the vault having already a certain elevation, it is necessary to heighten its roof. In the former case, the wall or floor of the mineral deposit is first penetrated by blasting with gunpowder. As soon as this penetration is effected over a certain length, parallel to the direction of the future vault, as happens at *b*, there is arranged on the bottom a horizontal layer of billets of firewood, over which other billets are piled in nearly a vertical position, which rests upon the ore, so that the flame in its expansion comes to play against the mineral mass to be detached. When, after some similar operations, the flame of the pile can no longer reach the ore of the roof on account of its height, a small terrace of rubbish must be raised on the floor of the deposit; and over this terrace a new pile of faggots is to be heaped up as above described. The ancient miners committed the fault of constantly placing such terraces close to the roof, and consequently arranging the faggots against this portion of the ore, so that the flame circulated from the roof down to the floor. The result of such procedure was the weakening of the roof, and the loss of much of the ore which could not be extracted from so unstable a fabric; and, besides, much more wood was burned than at the present day, because the action of the flame was dissipated in part against the whole mass of the roof, instead of being concentred on the portion of the ore which it was desired to dislodge. Now, the flame is usually made to circulate from the floor to the roof, in commencing a new vault.

When the vault has already a certain height, care is always taken that between the roof of the vault and the rubbish on which the pile is arranged, no more than two yards of space should intervene, in order that the flame may embrace equally the whole concavity of the vault, and produce an uniform effect on all its parts. Here, the pile is formed of horizontal beds, disposed crosswise above one another, and presents four free vertical faces, whence it has been called a *chest* by the miners.

It is usually on Saturday that the fire is applied to all the piles of faggots distributed through the course of the week. Those in the upper floors of exploitation are first burned, in order that the inferior piles may not obstruct, by their vitiated air, the combustion of the former. Thus, at 4 o'clock in the morning, the fires are kindled in the upper ranges; from pile to pile the fireman and his assistant descend towards the lower floors, which occupies them till 3 o'clock in the afternoon.

When the flame has beat for a few instants on the beds of ore, a strong odour of sulphur, and sometimes of arsenic, is perceived; and soon afterwards loud detonations are heard in the vaults. Suddenly the flame is seen to assume a blue colour, or even a white; and at this period, after a slight explosion, flakes of the ore, of greater or less magnitude, usually fall down on the fire, but the chief portion of the heated mineral still remains fixed to the vault. The ores pass now into a shattered and divided condition, which allows them afterwards to be detached by long forks of iron. In this manner the fire, volatilising entirely some constituents, such as sulphur, zinc, arsenic, and water, changing the aggregation of the constituent parts of the ore, and causing fissures by their unequal expansibilities, facilitates the excavation of such materials as resist by their tenacity the action of gunpowder.

The combustion goes on, without any person entering the mine, from Saturday evening till Monday morning, on which day the fireman and his assistants proceed to extinguish the remains of the bonfires. On Monday, also, some piles are constructed in the parts where the effect of the former ones has been incomplete; and they are kindled after the workmen have quitted the mines. On Tuesday all hands are employed in detaching the ores, in sorting them, taking them out, and preparing new piles against the next Saturday.

The labour of a week consists, for every man, of five posts during the day, each of 8 hours, and of one post of 4 hours for Saturday. Moreover, an extra allowance is made to such workmen as employ themselves some posts during the night.

The labour of one compartment, or *atelier*, of the mine consists, therefore, in arranging the faggots, in detaching the ore which has already experienced the action of the fire; in breaking the blocks obtained; in separating the ore from the *débris* of the pile; and, whenever it may be practicable or useful, in boring holes for blasting with gunpowder. The heat is so great in this kind of mine that the men are obliged to work in it without clothing.

We have already remarked that, besides the working by fire, which is chiefly used here, recourse is sometimes had to blasting by gunpowder. This is done in order either to recover the bottom part or ground of the vaults on which the fire can act but imperfectly, to clear away some projections which would interfere with the effect of the pile, or, lastly, to strip the surrounding rock from the mass of the ore, and thence to obtain schist proper for the construction of the rubbish-terraces.

The blasting-process is employed when the foreman of the workshop or mine-chamber judges that a hole well placed may separate enough of ore to pay the time, the repair of tools, and the gunpowder expended. But this indemnification is rarely obtained. The following statement will give an idea of the tenacity which the mineral deposit often presents:—

In a portion of the Rammelsberg mine, the ore, consisting of extremely compact iron and copper pyrites, was attacked by a single man, who bored a mining-hole. After 11 posts of obstinate labour, occupying altogether 88 hours, the workman, being vigilantly superintended, had been able to advance the hole to a depth of no more than 4 inches; in doing which he had rendered entirely unserviceable 126 punches or borers, besides 26 others which had been re-tipped with steel, and 201 which had been sharpened; 6¼ lbs. of oil had been consumed in giving him light; and ½ lb. of gunpowder was required for blasting the bore. It was found from a calculation made upon these facts by the administration of mines, that every inch deep of this hole cost, at their low price of labour, nearly a florin, value two shillings and sixpence.

It is therefore evident that, though the timber, of which the consumption is prodigiously great, were much less abundant and dearer than it still is at Rammelsberg, mining by fire would be preferable to every other mode of exploitation. It is even certain that, on any supposition, the employment of gunpowder would not be practicable for every part of the mine; and if fuel came to fail, it would be requisite to renounce the workings at Rammelsberg, although this mountain still contains a large quantity of metals.

If in all mines the free circulation of air be an object of the highest importance, we must perceive how indispensable it must be in every part of a mine where the mode of exploitation maintains the temperature of the air at 112° Fahr., when the workmen return into it after the combustion of the piles, and in which, besides, it is necessary that this combustion be effected with activity in their absence. But, in consequence of the extent and mutual ramifications of the workings, the number of the shafts, galleries, and their differences of level, the ventilation of the mine is in a manner spontaneously maintained. The high temperature is peculiarly favourable to it. The aid of art consists merely in placing some doors judiciously, which may be opened or shut at pleasure, to carry on the circulation of the air.

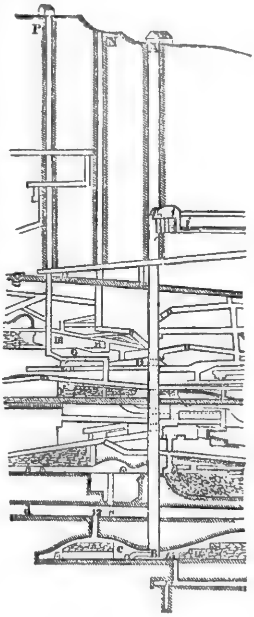
In considering the Rammelsberg from its summit, which rises about 400 yards above the town of Goslar, we observe, first, beds of slaty sandstone, which become the more horizontal, the nearer they approach to the surface. At about 160 yards below the top level there occurs, in the bosom of the slaty greywacke, a powerful stratum of shells embedded in a ferruginous limestone. In descending towards the face of the ore, the parallel stratification of the clay-slate, which forms its walls and roof, grows more and more manifest. Here the slate is black, compact, and thinly foliated. The inclination of the different beds of rock is considerable.

The ores are argentifereus and auriferous, but very slightly so, especially as to the gold. It is the ores of lead and copper which contain the silver, and in the latter the gold is found, but without its being well ascertained in what mineral it is deposited. Sometimes the ore occurs in the native state, or as copper of cementation. Beautiful crystals of sulphate of lime are found in the old workings.

In *figs.* 1475, 1476, A B is the shaft of extraction, called the *Kahnenkuhler*; N is the ventilation-shaft, called *Breïtlingerwetterschacht*; P is the extraction-shaft, called *Innier-schacht*.

E F is a new extraction-shaft, called *Neuertreibschacht*, by which also the water is pumped up; by A B and E F the whole extraction are carried on. The ores are raised in these shafts to the level of the waggon-gallery (*galerie de roulage*) *i*, by the whims 1, *q*, provided with ropes and buckets. 1, 2, 3, 4, *fig.* 1475, represent the positions of four water-wheels for working the whims; the first two being employed in extracting the ores, the last two in draining. The driving-stream is led to the wheel 1, along the drift *l*; whence it falls in succession upon the wheels 2, 3, 4. The general system of working consists of the following operations:—

1476



1. The bed of ore is got at by the transverse galleries *m*, *n*, *o*, *q*, *r*, *s*, which branch off from the extraction-shaft, and terminate at the wall of the main bed;
2. Great faults are scooped out at the level of the workings, by means of fire;
3. The roofs of these vaults are progressively propped with mounds of rubbish;
4. The ores thus detached, or by blasting with gunpowder, are then collected;
5. Lastly, they are brought out to the day, and washed near z.

Of the Instruments and Operations of Subterranean Mining.—It is by the aid of geometry, in the first place, that the miner studies the situation of the mineral deposits on the surface and in the interior of the ground; determines the several relations of the veins and the rocks; and becomes capable of directing the perforations towards a suitable end.

The instruments are:—

1. The magnetic compass, which is employed to indicate the direction of a metallic lode.
2. The graduated semicircle, which serves to measure the inclination or dip; this instrument is also called the clinometer.
3. The chain or cord for measuring the distance of one point from another.
4. When the neighbourhood of iron makes the use of the magnet uncertain, a plate or plane table is employed.

In order to penetrate into the interior of the earth, and to extract from it the objects of his toils, the miner has at his disposal several means, which may be divided into three classes:—1, *manual tools*; 2, *gunpowder*; 3, *fire*.

The tools used by the miners of Cornwall and Devonshire are the following:—

Fig. 1477. The *Pick*. It is a light tool, and somewhat varied in shape according to circumstances. One side used as a hammer is called the *poll*, and is employed to drive in the *gads*, or to loosen and detach prominences. The *point* is of steel, carefully tempered, and drawn under the hammer to the proper form. The French call it *pointerolle*.

Fig. 1478. The *Gad*. It is a wedge of steel, driven into crevices of rocks, or into small openings made with the point of the pick.

Fig. 1479. The *Miner's Shovel*. It has a pointed form, to enable it to penetrate among the coarse and hard fragments of the mine-rubbish. Its handle being somewhat bent, a man's power may be conveniently applied without bending his body.

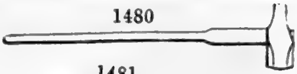
The *blasting-* or *shooting*-tools are:—a *sledge* or *mallet*, *fig.* 1480; *borer*, *fig.* 1481; *claying-bar*, *fig.* 1482; *needle* or *nail*, *fig.* 1483; *scraper*, *fig.* 1484; *tamping-bar*, *fig.* 1485.

Besides these tools, the miner requires a powder-horn; he is supplied with safety-fuse (see SAFETY-FUSE); tin cartridges for occasional use in wet ground; now more frequently is he supplied with cartridges made with well pitched paper.

The *borer*, *fig.* 1481, is an iron bar tipped with steel, formed like a thick chisel, and is used by one man holding it straight in the hole, with constant rotation on its axis, while another strikes the head of it with the iron sledge or mallet, *fig.* 1480. The hole is cleared out from time to time by the scraper, *fig.* 1484, which is a flat iron rod turned up at one end. If the ground be very wet, and the hole gets full of mud, it is cleaned out by a stick bent at the end into a fibrous brush, called a *swab-stick*.

Fig. 1486 represents the plan of blasting the rock, and a section of a hole ready for firing. The hole must be rendered as dry as possible, which is effected very simply by filling it partly with tenacious clay, and then driving into it a tapering iron rod, which nearly fills its calibre, called the *claying-bar* (*fig.* 1482). This being forced in with great violence, condenses the clay into all the crevices of the rock, and secures the dryness of the hole. When the hole is dry, and the charge of powder introduced, the *nail*, a small taper rod of copper, is inserted so as to reach the bottom of the hole, which is now ready for *tamping*. Different substances are employed for *tamping*, or cramming the hole, the most usual one being any soft species of rock free from siliceous or flinty particles. Small quantities of it only are introduced at a time, and rammed very hard by the *tamping-bar*, which is held steadily by one man, and struck with a sledge by another. The hole being thus filled, the nail is withdrawn by putting a bar through its eye, and striking it upwards. Thus a small perforation or vent is left for the safety-fuse which communicates the fire.

1480



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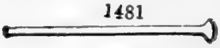

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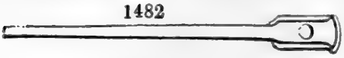

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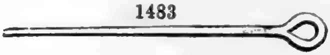

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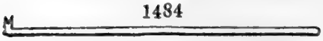

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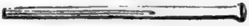

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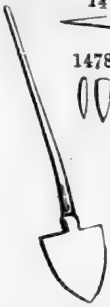
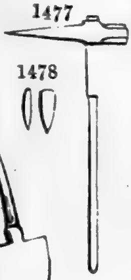
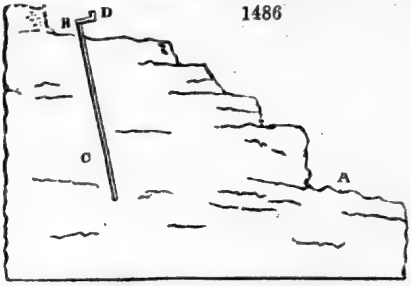


1477

1478



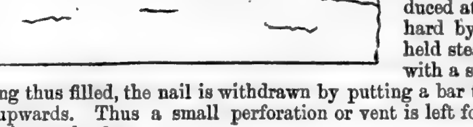
1486



For conveying the fire, the large and long green rushes which grow in marshy ground were formerly used in our mines, and are still used in some quarries. A slit is made in one side of the rush, along which the sharp end of a bit of stick is drawn, so as to extract the pith, when the skin of the rush closes again by its own elasticity. This tube is filled up with gunpowder, dropped into the vent-hole, and made ready with a bit of clay. A paper *smift*, adjusted to burn a proper time, is then fixed to the top of the rush-tube, and kindled, when the men of the quarry retire to a safe distance. The 'safety-fuse' is now, however, almost universally employed.

In *fig.* 1486 the portion of the rock which would be dislodged by the explosion is that included between A and B. The charge of powder is included in that part which fills the hole up to C; from which point to the top, the hole is filled with *tamping*. The old *smift* is shown at D.

1488



1487

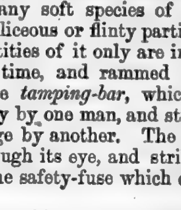


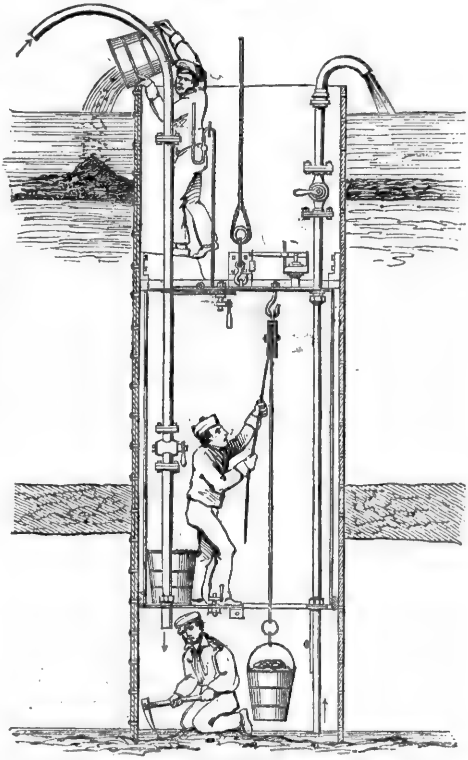
Fig. 1487 is an iron bucket, or, as it is called in Cornwall, a *kibble*, in which the ore is raised in the shafts, by machines called *whims* or *whimseys*, sometimes worked by horses, and frequently by steam-power. The best kibbles are made of sheet iron, and hold each about three hundred weight of ore: 120 kibbles are supposed to clear a cubic fathom of rock. In place of the kibble, *skips* running in guides fixed on the sides of the shafts are now used in the large and well-conducted mines.

Fig. 1488 represents the wheel-barrow used underground for conveying ore and waste to the foot of the shafts. It is made of light deal, except the wheel, which has a narrow rim of iron.

In all mines, to a greater or a less extent, there will be found accumulations of water; it is necessary, therefore, to adopt measures to ensure its removal. The mineral treasures, being brought to the surface, necessarily undergo a process of 'dressing,' that is, the separation of the richer from the poorer portion. For a full account of dressing machinery, &c., see DRESSING OF ORES.

It sometimes happens that the necessities of mining demand the construction of shafts in places covered with water. Some years since a very extraordinary case of this kind was carried out at the Wherry Mine, near Penzance, where a cylinder of wood, rising through the sea, formed the entrance to a shaft sunk into the mine. In a storm a ship ran against this wooden structure and destroyed it.

1489



M. Triger, engineer in the department of Maine and Loire, had the idea of making a well in the very bed of the Loire by means of compressed air. A cylinder of thin iron, *fig.* 1489, serving as a cutting machine, was sunk into the alluvium; it was separated into three compartments by horizontal partitions. The upper compartment remained always open, the lower compartment was the workshop, and between them was the middle one, which served as the chamber of equilibrium, designed to be put in communication with either the compartment above or the one below. The things being so disposed, they forced into the bottom compartment, air compressed by a vapour-machine without intermission. This air drove the water up a tube, of which the lower part was buried in the bottom of the excavation, and of which the upper part was raised above the cylinder. The workmen were then able to penetrate the first apartment and open the second, which was afterwards hermetically closed, and in which the air of ordinary pressure was put in communication with the compressed air in the third. Having arrived in the third compartment, they excavated the sands, and caused the machine to descend. As they accumulated, the sands excavated in the middle compartment, they had only to remove them by shutting the communication with the bottom and opening that of the top. A pressure sufficient to balance the exterior waters was maintained during the work, without sensibly incommoding the workmen.

It is evident that wells dug in the water-saturated earths must immediately be cased, that is to say, covered with a casing of wood, of masonry, or of iron, solid and impermeable, which is able to resist the infiltration and pressure of the waters at the same time.

For a description of the machine employed for facilitating the ascent and descent of miners, see Man Engine.

MINING FOR COAL. The processes of boring, by which it is usual to begin for the purpose of determining the existence and depth of any bed or beds of coal, have been already described. See Boring.

Of Winning a Coal-field.—In sinking a shaft for working coal, the great obstacle to be encountered is water, particularly in the first opening of a field, which proceeds from the surface of the adjacent country; for every coal-stratum, however deep it may lie in one part of the basin, always rises till it meets the alluvial cover, or *crops out*, unless it be met by a slip or dyke. When the basset-edge of the strata is covered with gravel or sand, any body or stream of water will readily percolate downwards through it, and fill up the porous interstices between the coal-measures, till arrested by the face of a slip, which acts as a natural dam, and confines the water to one compartment of the basin, which may, however, be of considerable area, and require a great power of drainage.

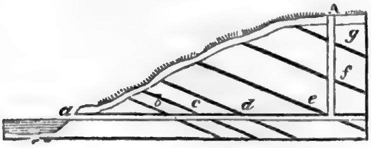
In reference to water, coal-fields are divided into two kinds: 1, level free coal; 2, coal not level free. In the practice of mining, if a coal-field, or portion of it, is so situated above the surface of the ocean that a level can be carried from that plane till it intersects the coal, all the coal above the plane of intersection is said to be level free; but if a coal-field, though placed above the surface of the ocean, cannot, on account of the expense, be drained by a level or gallery, such a coal-field is said to be not level free.

Besides these general levels of drainage, there are subsidiary levels, called off-takes or drifts, which discharge the water of a mine, not at the mouth of a pit, but at some depth beneath the surface, where, from the form of the country, it may be run off level free. From 20 to 30 fathoms off-take is an object of considerable economy in pumping; but even less is often had recourse to; and when judiciously contrived, may serve to intercept much of the crop water, and prevent it from getting down to the dip part of the coal, where it would become a heavy load on a hydraulic or pumping engine.

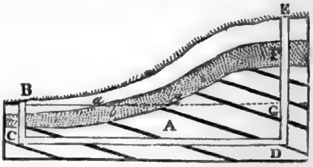
Day-levels were an object of primary importance with the early miners, who had not the gigantic pumping power of the steam-engine at their command. Levels ought to be no less than 4 feet wide, and from 5 feet and a half to 6 feet high: which is large enough for carrying off water, and admitting workmen to make repairs and clear out depositions. When a day-level, however, is to serve the double purpose of drainage, and an outlet for coals, it should be at least 5 feet wide, with its bottom gutter for drainage either covered over or open. In other instances a level not only carries off the water from the colliery, but is converted into a canal for bearing boats loaded with coals for the market. Some subterranean canals are 9 feet wide, and 12 feet high, with 5 feet depth of water.

If, in the progress of driving a level, workable coals are intersected before reaching the seam which is the main object of the mining adventure, an air-pit may be sunk, of such dimension as to serve for raising the coals. These air-pits do not in general exceed 9 feet in diameter; and they ought to be always cylindrical. *Fig.* 1490 represents a coal-field where the winning is made by a day-level; *a* is the mouth of the gallery on a level with the sea; *b*, *c*, *d*, *e*, are intersected coal-seams, to be drained by the gallery. But the coals beneath this level must obviously be drained by pumping. A represents a coal-pit sunk on the coal *e*; and if the gallery be pushed forward the coal-seams, *f*, *g*, and any others which lie in that direction, will also be drained, and then worked by the pit A. The chief obstacle to the execution of day-levels, is presented by quicksands in the alluvial cover, near the entrance of the gallery. The best expedient to be adopted amid this difficulty is the following:—*Fig.* 1491 represents the strata of a coal-field A, with the alluvial earth *a*, *b*, containing the bed of quicksand *b*. The lower part, from which the gallery is required to be carried, is shown by the line B G. But the quicksand makes it impossible to push forward this day-level directly. The pit B C must therefore be sunk through the quicksand by means of *tubbing* (to be presently described), and when the pit has descended a few

1490



1491



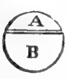
yards into the rock, the gallery or drift may then be pushed forward to the point D, when the shaft E D is put down, after it has been ascertained by boring that the rock-head or bottom of the quicksand at F is a few yards higher than the mouth of the small pit B. During this operation, all the water and mine-stuff are drawn off by the pit B; but whenever the shaft E D is brought into communication with the gallery, the water is allowed to fill it from C to D, and rise up both shafts till it overflows at the orifice B. From the surface of the water in the deep shaft at G, a gallery is begun of the common dimensions, and pushed onwards till the coal sought after is intersected. In this way no drainage-level is lost. This kind of drainage-gallery, in the form of an inserted syphon, is called a drowned or a blind level.

When a coal-basin is so situated that it cannot be rendered level free, the winning must be made by the aid of machinery. The engines at present employed in the drainage of coal mines are:—the water-wheel, the water-pressure engine, and the steam-engine. See Hydraulic Machinery.

The depth at which the coal is to be won, or to be drained of water, regulates the power of the engine to be applied, taking into account the probable quantity of water which may be found, a circumstance which governs the diameter of the working barrels of the pumps. Experience has proved, that in opening collieries, even in new fields, the water may generally be drawn off by pumps of from 10 to 20 inches diameter; excepting where the strata are connected with rivers, sand-beds filled with water, or marsh-lands. As feeders of water from rivers or sand-beds may be hindered from descending coal-pits, the water proceeding from these sources need not be taken into account; and it is observed, in sinking shafts, that though the influx which cannot be cut off from the mine may be at first very great, even beyond the power of the engine for a little while, yet as this excessive flow of water is frequently derived from the drainage of fissures, it eventually becomes manageable. The pumping machinery of a new colliery should be adequate to pump the water in 8 or 10 hours out of the 24. In the course of years many water-logged fissures come to be cut by the workings, and the coal-seams get excavated towards the outcrop, so that a constant increase of water ensues, and thus a colliery which has been long in operation, frequently becomes heavily loaded with water, and requires the action of its hydraulic machinery both night and day.

Of Engine-pits.—In every winning of coal, the shape of the engine-pit deserves much consideration. For shafts of moderate depth, many forms are in use; as circular, oval, square, octagonal, oblong-rectangular, and oblong-elliptical. In pits of inconsiderable depth, and where the earthy cover is firm and dry, any shape deemed most convenient may be preferred; but in all deep shafts, no shape but the circular should be admitted. Indeed, when the water-run requires to be stopped by tubbing or cribbing, the circular is the only shape which presents a uniform resistance in every point to the equable circumambient pressure. The elliptical form is the next best, when it deviates little from the circle; but even it has almost always given way to a considerable pressure of water. The circular shape has the advantage, moreover, of strengthening the shaft walls, and is less likely to suffer injury than other figures, should any failure of the pillars left in working out the coal cause the shaft to be shaken by subsidence of the strata. The smallest engine-pit should be ten feet in diameter, to admit of the pumps being placed in the lesser segment, and the coals to be raised in the larger one, as shown in *fig.* 1492, which is called a double pit. If much work is contemplated in drawing coals, particularly if their masses be large, it would be advantageous to make the pit more than 10 feet wide. When the area of a shaft is to be divided into three compartments, one for the engine-pumps, and two for raising coals, as in *fig.* 1493, which is denominated a triple pit, it should be 12 feet in diameter. If it is to be divided into four compartments, and made a quadrant shaft, as in *fig.* 1494, with one space for the pumps, and three for ventilation and coal-drawing, the total circle should be 15 feet in diameter. These dimensions are, however, governed by local circumstances, and by the daily discharge of coals.

1492



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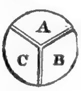

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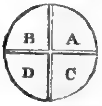


If there is a large quantity of water to pump, it is most desirable to appropriate a shaft exclusively for the purpose. Another shaft being used for raising coal, and as an upcast for the ventilation of the mine.

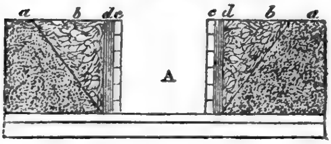
When only one shaft is sunk, and divided by wood or stone partitions, the ventilation of the mine is dependent upon these slight divisions of the shaft. If the partitions of a shaft become injured or burnt, which has been the case with wood partitions, the ventilation of the mine may suddenly be destroyed. Many lives have been placed in great jeopardy by the burning of wood partitions, which has destroyed the ventilation and prevented escape up the shaft.

The most approved arrangement of shafts for a large colliery yielding explosive gas, and where water has to be pumped, is to sink a shaft for pumping, another for raising coals, and a third for ventilation or upcast; at the bottom of which is kept burning a large furnace.

The shaft, as it passes through the earthy cover, should be securely faced with masonry of jointed ashlar, having its joints accurately bevelled to the centre of the circle.

When the alluvial cover is a soft mud, recourse must be had to the operation of tubbing. A circular tub, of the requisite diameter, is made of planks from 2 to 3 inches thick, with the joints bevelled by the radius of the shaft, inside of which are cribs of hard wood, placed from 2 to 4 feet asunder, as circumstances may require. These cribs are constructed of the best heart of oak, sawn out of the natural curvature of the wood, adapted to the radius, in segments from 4 to 6 feet long, from 8 to 10 inches in the bed, and 5 or 6 inches thick. The length of the tub is from 9 to 12 feet, if the layer of mud have that thickness; but a succession of such tubs must be set on each other, provided the body of mud be thicker. The first tub must have its lower edge thinned all round, and shod with sharp iron. If the pit be previously secured to a certain depth, the tub is made to pass within the cradling, and is lowered down with tackles till it rests fair among the soft alluvium. It is then loaded with iron weights at top, to cause it to sink down progressively as the mud is removed from its interior. Should a single tub not reach the solid rock (sandstone or basalt), then another of like construction is set on, and the gravitating force is transferred to the top. *Fig.* 1495, represents a bed of quicksand resting on a bed of impervious clay, that immediately covers the rock. A is a finished shaft; *a a*, the quicksand; *b b*, the excavation necessarily sloping much outwards; *c c*, the lining of masonry; *d d*, the moating or puddle of clay, hard rammed in behind the stone-work, to render the latter water-tight. In this case, the quicksand being thin in body, has been kept under for a short period, by the hands of many men scooping it rapidly away as it filled in. But the most effectual method of passing through beds of quicksand, is by means of cast-iron cylinders; called therefore, cast-iron tubbing. When the pit has a small diameter, these tubs are made about 4 feet high, with strong flanges and bolt holes inside of the cylinder, and a counterfort ring at the neck of the flange, with brackets: the first tub, however, has no flange at its lower edge, but is rounded to facilitate its descent through the mud. Should the pit be of large diameter, then the cylinders must be cast in segments of 3, 4, or more pieces, joined together with inside vertical flanges, well jointed with oakum and white-lead. When the sand-bed is thick, eighty feet, for instance, it is customary to divide that length into three sets of cylinders, each thirty feet long, and so sized as to slide within each other, like the eye-tubes of a telescope. These cylinders are pressed down by heavy weights, taking care to keep the lower part always further down than the top of the quicksand, where the men are at work with their shovels, and where the bottom of the pumps hangs for withdrawing the surface water.

1495

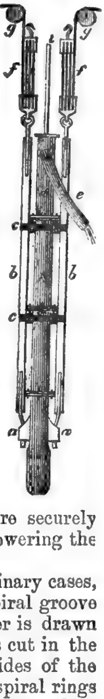


The engine-pit being secured, the process of sinking through the rock is ready to be commenced, as soon as the divisions of the pit formed of carpentry, called brattices, are made. In common practice, and where great tightness of joining is not required, for ventilating inflammable air, bars of wood called buntons, about 6 inches thick and 9 deep, are fixed in a horizontal position across the pit, at distances from each other of 10, 20, or 30 feet, according to circumstances. Being all ranged in the same vertical plane, deals an inch and a half thick are nailed to them, with their joints perfectly close; one half of the breadth of a bunton being covered by the ends of the deals. In deep pits, where the ventilation is to be conducted through the brattice, the side of the buntons next the pumps is covered with deals in the same way, and the joints are rendered secure by being caulked with oakum. Fillets of wood are also fixed all the way down on each side of the brattice, constituting what is called a double pit.

When a shaft is to have 3 compartments, it requires more care to form the brattice, as none of the buntons stretch across the whole space, but merely meet near the middle, and join at certain angles with each other. As the buntons must therefore sustain each other, on the principle of the arch, they are not laid in a horizontal plane, but have a rise from the sides towards the place of junction of 1 or 9 inches, and are bound together by a three-tongued iron strap. Fillets of wood are carried down the whole depth, not merely at the joinings of the brattice with the sides of the pit, but also at their central place of union; while wooden pillars connect the centre of each set of buntons with those above and below. Thus the carpentry work acquires sufficient strength and stiffness.

In quadrant shafts the buntons cross each other towards the middle of the pit, and are generally let into each other about an inch, instead of being half-checked. *Fig.* 1492 is a double shaft: A, the pump pit; B, the pit for raising coal. *Fig.* 1493 is a triple shaft; in which A is the pump compartment; B and C are coal pits. *Fig.* 1494 is a quadrant shaft: A, the pump pit; B, pit for ventilation or upcast for the smoke; C and D, pits for raising coals.

1496



Whenever the shaft is sunk so low that the engine is needed to remove the water, the first set of pumps may be let down, by the method represented in *fig.* 1496; where A is the pump; *a a*, strong ears through which pass the iron rods connected with the spears *b b*; *c c*, are the lashings; *d*, the hoggar pump; *e*, the hoggar; *f f*, the tackles; *g g*, the single pulleys; and *i*, the pump-spears. By this mechanical arrangement the pumps are sunk in the most gradual manner, and of their own accord, so to speak, as the pit descends. To the arms of the capstans, sledges are fastened with ropes or chains; the sledges are loaded with weights, as counterpoises to the weight of the column of pumps, and when additional pumps are joined in, more weight is laid on the sledges. As the sinking set of pumps is constantly descending, and the point for the delivery of the water above always varying, a pipe, of equal diameter with the pumps, and about 11 feet long, but much lighter in metal, is attached to *e*, and is terminated by a hose of leather, of sufficient length to reach the cistern where the water is delivered. This is called the hoggar-pipe. In sinking, a vast quantity of air enters with the water, at every stroke of the engine; and therefore the lifting stroke should be very slow, and a momentary stop should take place before the returning stroke, to suffer all the air to escape. As the working barrels are generally 9 or 10 feet long, and the full stroke of the engine from 7 to 8 feet, when at regular work, it is customary to diminish the length of stroke, in sinking, to about 6 feet; because, while the pumps are constantly getting lower, the bucket in the working barrel has its working range progressively higher.

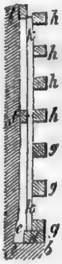
Another method of suspending the pumps in the sinking shaft, in the place of the ropes and blocks, is by two powerful iron screws about 15 feet in length, which are supported at the top of the shaft by strong beams of timber. As the shaft is sunk, the pumps are lowered by the screws; when lowered sufficient for a pump 9 feet in length, the pumps are securely fastened, while the screws are detached and screwed up ready for again lowering the pumps as the shaft is sunk.

The water obtained in sinking through the successive strata is, in ordinary cases, conducted down the walls of the shaft; and if the strata are compact, a spiral groove is cut down the sides of the shaft, and when it can hold no more, the water is drawn off in a spout to the nearest pump-cistern; or a perpendicular groove is cut in the side of the shaft, and a square box-pipe either sunk in it, flush with the sides of the pit, or it is covered with deal boards well fitted over the cavity. Similar spiral rings are formed in succession downwards, which collect the trickling streams, and conduct them into the nearest cistern; or rings made of wood or cast iron, are inserted flush with the sides of the pipe; and the water is led from one ring to another, through perpendicular pipes, until the undermost ring is full, when it delivers its waters into the nearest pump-cistern. Keeping the shaft dry is very important to the comfort of the miners, and the durability of the work.

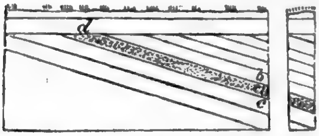
When an engine shaft happens to pass through a great many beds of coal, a gallery a few yards long is sometimes driven into each coal-seam, and a bore then put down from one coal-seam to another, so that the water of each may pass down through these bores to the pump-cisterns. The water is more frequently taken down the shaft in pipes to the nearest cistern.

While a deep pit is sinking, a register is kept of every part of the excavations, and each feeder of water is measured daily, to ascertain its rate of discharge, and whether it increases or abates. The mode of measurement is by noting the time, with a seconds watch, in which a cistern of 40 or 50 gallons gets filled. There are modes of keeping back or stopping up these feeders, by plank tubbing, iron tubbing, and by oak cribs. Let *fig.* 1497 represent the sinking of a shaft through a variety of strata, having a top cover of sand, with much water resting on the rock summit. Each plane of the coal-measure rises in a certain direction till it meets the alluvial cover. Hence the pressure of the water at the bottom of the tubbing that rests on the summit of the rock is as the depth of water in the superficial alluvium; and if a stratum *a* affords a great body of water, while the superjacent stratum *b*, and the subjacent *c*, are impervious to water; if the porous bed *a* be 12 feet thick, while no water occurs in the strata passed through from the rock-head, until the depth (supposed to be 50 fathoms from the surface of the water in the cover); in this case, the tubbing or cribbing must sustain the sum of the two water-pressures, or 62 fathoms; since the stratum *a* meets the alluvial cover at *d*, the fountain-head of all the water that occurs in sinking. Thus we perceive, that though no water-feeder of any magnitude should present itself till the shaft had been sunk 100 fathoms; if this water required to be stopped up or tubbed off through the breadth of a stratum only 3 feet thick, the tubbing would need to have a strength to resist 100 fathoms of water-pressure. For though the water at first oozes merely in discontinuous particles through the open pores of the sands and sandstones, yet it soon fills them up, like a myriad of tubes, which transfer to the bottom the total weight of the hydrostatic column of 100 fathoms; and experience shows, as we have already stated, that whatever water occurs in coal-pits, or in mines, generally speaking, proceeds from the surface of the ground. Hence, if the cover be an impervious bed of clay, very little water will be met with among the strata, in comparison with what would be found under sand.

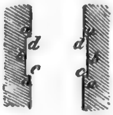
1499



1497



1498



When several fathoms ot tne strata must be tubbed, in order to stop up the water-flow, the shaft must be widened regularly to admit the kind of tubbing that is to be inserted; the greatest width being needed for plank-tubbing, and the least for iron-tubbing. *Fig.* 1498 represents a shaft excavated for plank-tubbing, where *a*, *a*, *a*, *a* are the impervious strata, *b*, *b* the porous beds water-logged, and *c*, *c* the bottom of the excavation, made level and perfectly smooth with mason chisels. The same precautions are taken in working off the upper part of the excavation *d*, *d*. In this operation, three kinds of cribs are employed; called wedging, spiking, and main cribs. Besides the stout plank for making the tub, a quantity of well-seasoned and clean reeded deal is required for forming the joints; called sheeting deal by the workmen. This sheeting deal is always applied in pieces laid endwise, with the end of the fibres towards the area of the pit. Since much of the security from water depends on the tightness of the tub at its jointing with the rock, several plans have been contrived to effect this object; the most approved being represented in *fig.* 1499. To make room for the lower wedging crib, the recess is excavated a few inches wider, as at *c*; and from *b* to *c*, sheeting deals are laid all round the circle, or a thin stratum of oakum is introduced. On this the wedging crib *d* is applied, and neatly jointed in the radius-line of the pit, each segment being drawn exactly to the circle: and at each of its elements sheeting deal is inserted. This wedging crib must be 10 inches in the bed, and 6 inches deep. The vacuity *e*, at the back of the crib, about 2 and a half inches wide, is filled with pieces of dry clean reeded deal, inserted endwise; which is regularly wedged with one set of wedges all round, and then with a second and a third set of wedges, in the same regular style, to keep the crib in a truly circular posture. By this process, well executed, no water can pass downwards by the back of the crib. The next operation is to fix spiking cribs *f*, to the rock, about 10 or 12 feet from the lower crib, according to the length of the planks to be used for the tubs. They must be set fair to the sweep of the shaft, as on them its true circular figure depends. The tubbing deals, *k*, must now be fixed. They are 3 inches thick, 6 broad, and planed on all sides, with the joints accurately worked to the proper bevel for the circle of the pit. The main cribs, *g g*, are then to be placed as counterforts, for the support and strength of the tubbing. The upper ends of the first set of tub-planks being cut square and level all round, the second spiking crib, *l*, is fixed, and another set of tubbing deals put round like the former, having sheeting deal inserted betwixt the ends of the two sets at *f*. When this is wedged, the cribs, *h h*, are placed.

Oak cribbing is made with pieces of the best oak, from 3 to 4 feet long, 10 inches in the bed, and 7 or 8 inches deep.

The third mode of tubbing, by means of iron cylinders cast in segments, now supersedes the wooden tubbing, from the great reduction in the price of iron, and its superior strength and durability. Each segment is adjusted piece to piece in the circular recess of the pit cut out for their reception. The flange for the wedging joint is best turned inwards. In late improvements of this plan, executed by Mr. Buddle, where the pressure amounted to several hundred feet, the segments were 6 feet long, 2 feet broad, and an inch thick, counterforted with ribs or raised work on the back; the lip of the flange was strong, and supported by brackets.

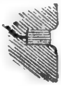
These segments of the iron cylinder are set true to the radius of the pit; and every horizontal and perpendicular joint is made tight with a layer of sheeting deal. A wedging crib is fixed at the bottom, and the segments are built up regularly with joints like ashlar-work. This kind of tubbing can be carried to any height, till the water finds an outlet at the surface, or till strata containing water can be tubbed off, as by the modes of tubbing already described. A shaft finished in this manner presents a smooth lining-wall of iron, the flanges being turned towards the outside of the cylinders. In this iron tubbing, no screw bolts are needed for joining the segments together; as they are packed hard within the pit, like the staves of a cask.

The weight of the hydrostatic column is not the only pressure to which the tubbing is exposed. There is the pressure from accumulated carburetted hydrogen gas, which considerably exceeds the water-pressure. If the tubbing in deep shafts was put in without pressure pipes, it would be liable to be fractured by great pressure from gas. The pressure pipes are usually fixed to each length of tubbing; strong taps or cocks are first screwed into the tubbing, and malleable iron pipes of from 1 to 2 inches in diameter are fixed to the tops and carried up to the surface; and in many cases a continual overflow of gas and water issues. By these means the tubbing is only subject to the pressure due to the hydrostatic column.

Before tubbing a shaft, it is necessary to ascertain whether the strata containing water is likely to be dislocated, so as to let down the water by working the coal away; in such a case, tubbing the shaft is unnecessary. The judgment of the mining engineer must decide about this.

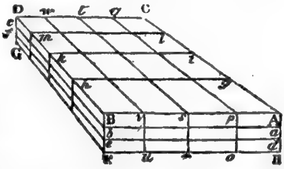
When a porous thin bed or parting betwixt two impervious strata gives out much water, or when the fissures of the strata, called cutters, are very leaky, the water can be completely stopped up by the improved process of wedging. The fissure is cut open with chisels, to a width of 2, and a depth of 7 inches, as represented in *fig.* 1500. The lips being rounded off about an inch and a half, pieces of clean deal are then driven in, whose face projects no further than the contour of the lips, when the whole is firmly wedged, till the water is entirely stopped. By sloping back the edges of the fissures, and wedging back from the face of the stone, it is not liable to burst or crack off in the operation, as took place in the old way, of driving in the wedge directly.

1500



Messrs. Kind and Chaudron's improved methods of sinking shafts through water-bearing strata and beds of quicksand, successfully practised in many of the continental coal-fields, are fully described in the article BORING.

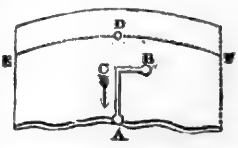
1501



Working of Coal.—A stratum, bed, or seam of coal, is not a solid mass, of uniform texture, nor always of homogeneous quality. It is often divided and intersected, with its concomitant strata, by what are named partings, backs, cutters, reeds, or ends. Besides the chief partings at the roof and pavement of the coal-seam, there are subordinate lines of parting in the coal mass, parallel to these, of variable dimensions. These divisions are delineated in *fig.* 1501, where A, B, C, D, E, F, G, represent a portion of a bed of coal; the parallelogram A B D C the parting at the roof, and E F G the parting at the pavement; *a b*, *b c*, *d e*, and *e f*, are the subordinate or intermediate partings; *g h*, *i k*, *l m*, the backs; *o p*, *p q*, *r s*, *s t*, *u v*, and *v w*, the cutters. It is thus manifest that a bed of coal, according to the number of these natural divisions, is subdivided into solid figures of various dimensions, and of a cubical or rhomboidal shape.

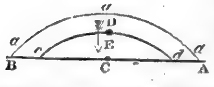
When the engine-pit is sunk, and the lodgement formed, a heading or drift is then made in the coal to the rise of the field, or a cropping from the engine-pit to the second pit. This heading may be 6 or 8 feet wide, and carried either in a line directly to the pit bottom, or at right angles to the backs or web of the coal, until it is on a line with the pit, where the heading is set off, upon one side, to the pit bottom. This heading is carried as nearly parallel to the backs as possible, till the pit is gained. *Fig.* 1502 represents this mining operation. A, is the engine-pit. B, the second or bye-pit, A C, the gallery or heading driven at right angles to the backs. C B, the gallery set off to the right hand, parallel to the backs. The next step is to drive the main levels from the engine-pit bottom. In this business the best colliers are always employed, as the object is to drive the gallery in a truly level direction, independently of all sinkings or risings of the pavement. For coal-seams of ordinary thickness, this gallery is usually not more than 6 feet wide; observing to have on the dip side of the level a small quantity of water, like that of a gutter, so as to guide the workmen in

1502



driving the level. When the level is driven correctly, with the proper depth of water, it is said to have dead water at the face. In this operation, therefore, the miner pays no regard to the backs or cutters of the coal; but is guided in his line of direction entirely by the water-level, which he must attend to solely, without regard to slips or dislocations of the strata throwing the coal up or down. In the last figure, the coal-field is a portion of a basin; so that if the shape be uniform and unbroken, and if any point be assumed on the dip of the crop, as D, the level lines from that point will be parallel to the line of crop, as D E, D F, and the levels from any point, whatever the dip or inclination of strata, will be also parallel to these; and hence, were the coal-field an entire elliptical basin, the dip-head levels carried from any point would be elliptical, and parallel to the crop. If, as is more commonly the case, the coal-field be merely a portion of a basin, formed by a slip of the strata, as represented in *fig.* 1503, where *a, a, a* is the crop and A B, a slip of great magnitude, forming another coal-field on the side C, then the crop not only meets the alluvial cover, but is cut off by the slip at A and at B. Should any point, therefore, be assigned for an engine-pit, the levels from it will proceed in a line parallel to the crop, as D *d*, D *c*; and the level on both sides of the engine-pit will be also cut off by the slip A B. In this figure, the part included between the two curve lines is the breadth or breast of coal-field won by the engine-pit D; what is not included is termed the under-dip coal, and can be worked only by one or more new winnings towards the dip, according to circumstances.

1503



In British practice, there are four different systems of working coal-mines.

1. Working with pillars and rooms or boards, styled post and stall, where the pillars left bear such proportion to the coal excavated as is just adequate to the support of the incumbent strata.

2. Working with post and stall, where the pillars are left of an extra size, and stronger than may be requisite for bearing the superior strata, with the intention of removing a considerable portion of each massive pillar, whenever the regular working of post and stall has been finished in the colliery.

3. Working with post and stall, or with comparatively narrow rooms or boards, whereby an uncommonly large proportion of coal is left, with the view of working back towards the pits, whenever the colliery is worked in this manner to the extent of the coal-field, and then taking away every pillar completely, if possible, and allowing the whole superincumbent strata to crush down, and follow the miners in their retreat.

4. Working the long way, being the Shropshire and Derbyshire method; which leaves no pillars, but takes out all the coal progressively as the workings advance. On this plan the incumbent strata crush down, creeping very close to the heads of the miners.

The post-and-stall system is practised with coals of every thickness. The long-work method is adopted generally with thin coals; for when the thickness exceeds 6 or 7 feet, and there is only little refuse made in excavating the coal to cart into the excavated part, this mode has been found impracticable.

The following considerations must be had in view in establishing a coal-mine:—

1. The lowest coal stratum of the winning should be worked in such a manner as not to injure the working or the value of the upper coals of the field; but, if this cannot be done, the upper coals should be worked in the first place. There are, however, cases where an upper seam of coal can be worked more advantageously by working a lower seam first on the long-wall method.

2. The coals must be examined as to texture, hardness, softness, the number and openness of the backs and cutters.

3. The nature of the pavement of the coal-seam, particularly as to hardness and softness; and if soft, to what depth it may be so.

4. The nature of the roof of the coal-seam, whether compact, firm, and strong; or weak, and liable to fall; as also the nature of the superincumbent strata.

5. The nature of the alluvial cover of the ground, as to water, quicksands, &c.

6. The situation of rivers, lakes, or marshes; particularly if any be near the outcrop of the coal-strata.

7. The situation of towns, villages, and mansion-houses, upon a coal-field as to the chance of their being injured by any particular mode of mining the coal.

Mr. Bald gives the following general rules for determining the best mode of working coal by post and stall:—

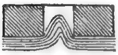
'1. If the coal, pavement, and roof, are of ordinary hardness, the pillars and rooms may be proportioned to each other, corresponding to the depth of the superincumbent strata, providing all the coal proposed to be wrought is taken away by the first working, as in the first system; but, if the pillars are to be winged, or partially worked afterwards, they must be left of an extra strength, as in the second system.

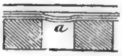
'2. If the pavement is soft, and the coal and roof strong, pillars of an extra size must be left, to prevent the pillars sinking into the pavement, and producing a creep.

'3. If the coal is very soft, or has numerous open backs and cutters, the pillars must be left of an extra size, otherwise the pressure of the superincumbent strata will make the pillars fly or break off at the backs and cutters, the result of which would be a total destruction of the pillars, termed a crush or sit, in which the roof sinks to the pavement, and closes up the work.

'4. If the roof is very bad, and of a soft texture, pillars of an extra size are required, and the rooms or boards comparatively very narrow.

'In short, keeping in view all the circumstances, it may be stated generally, that when the coal, pavement, and roof, are good, any of the systems before mentioned may be pursued in the working; but if they are soft, the plan is to work with rooms of a moderate width, and with pillars of great extra strength, by which the greater part of the coal may be got out at the last of the work, when the miners retreat to the pit bottom, and there finish the workings of a pit.'


1504

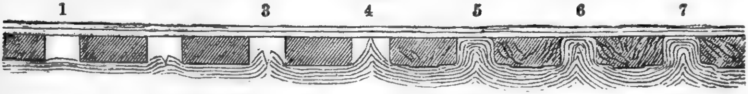


1505

Fig. 1504 represents the effect of pillars sinking into the pavement, and producing a creep; and *fig.* 1505 exhibits large pillars and a room, with the roof stratum bending down before it falls at *a*. Thus the roads will be shut up, the air-courses destroyed, and the whole economy of the mining operations deranged.

In the 'Report from the Select Committee of the House of Lords, appointed to take into consideration the state of the Coal Trade in the United Kingdom,' printed in June 1829, under the head of Mr. Buddle's evidence, we have an excellent description of the nature and progress of creeps, which we have adverted to in the preceding account. The annexed figure (1506) exhibits the creep in all its progressive stages, from its commencement until it has completely closed all the workings, and crushed the pillars of coal. The section of the figures supposes us standing on the level of the different galleries which are opened in the seam. The black is the coal pillars between each gallery; when these are weakened too much, or, in other words, when their bases become too narrow for the pavement below, by the pressure of the incumbent strata, they sink down into the pavement, and the first appearance of creep is a little curvature in the bottom of each gallery: that is, the first symptom obvious to sight; but it may generally be heard before it is seen. The next stage is when the pavement begins to open with a crack longitudinally. The succeeding stage is when that crack is completed, and it assumes the shape of a metal ridge. The next is when the metal ridge reaches the roof. The following stage is when the peak of the metal ridge becomes flattened by pressure, and forced into a horizontal direction, and becomes quite close; just at this moment the coal pillars begin to sustain part of the pressure. The next is when the coal pillars take part of the pressure. The last stage is when it is dead and settled, that is, when the metal or factitious ridge, formed by the sinking of the pillar into the pavement, bears, in common with the pillars of coal on each side, the full pressure, and the coal becomes crushed or cracked, and can be no longer worked, except by a very expensive and dangerous process.

1506

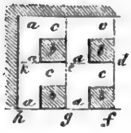


1. First stage of active creep.
2. Second do.
3. Third do.
4. Fourth do.
5. The metal ridge closed, and the creep beginning to settle.
6 and 7. The creep settled, the metal ridges being closely compressed, and supporting the roof.

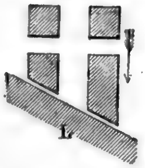
The proportion of coal worked out, to that left in the pillars, when all the coal intended to be removed is taken out at the first working, varies from four-fifths to two-thirds; but, as the loss of even one-third of the whole area of coal is far too much, the better mode of working, suggested in the third system, ought to be adopted.

The proportion of a winning to be worked may be thus calculated:—Let *fig.* 1507 be a small portion of the pillars, rooms, and thirlings, formed in a coal-field; *a*, *a*, are two rooms; *b*, the pillars; *c*, the thirlings (or area worked out). Suppose the rooms to be 12 feet wide, the thirlings to be the same, and the pillars 12 feet on each side; adding the face of the pillar to the width of the room, the sum is 24; and also the end of the pillar to the width of the thirling, the sum is likewise 24; then $24 \times 24 = 576$; and the area of the pillar is $12 \times 12 = 144$; and as 576 divided by 144 gives 4 for a quotient, the result is, that one-fourth of the coal is left in pillars, and three-fourths extracted. Let *d*, *e*, *f*, *g*, be one winning, and *g*, *e*, *k*, *h*, another. By inspecting the figure, we perceive the workings of a coal-field are resolved into quadrangular areas, having a pillar situated in one of the angles.

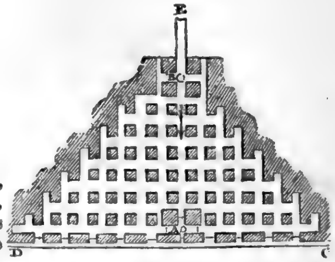
1507



1508



1509



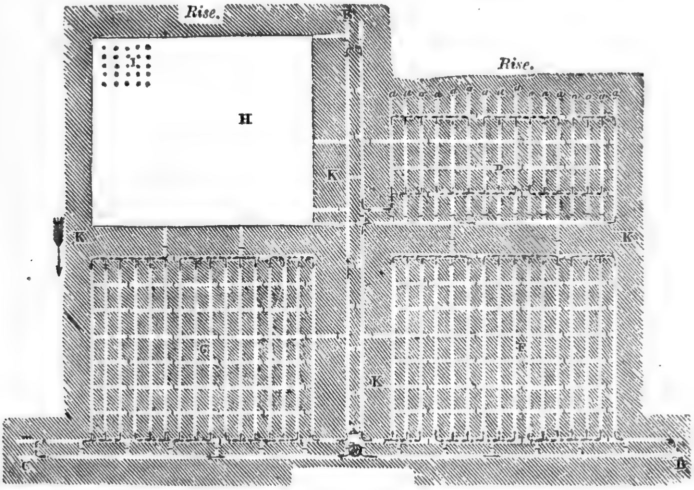
In forming the pillars and carrying forwards the boards with regularity, especially where the backs and cutters are very distinct and numerous, it is of importance to work the rooms at right angles to the backs, and the thirlings in the direction of the cutters, however oblique these may be to the backs, as the rooms are by this means conducted with the greatest regularity with regard to each other, kept equidistant, and the pillars are strongest under a given area. At the same time, however, it seldom happens that a back or cutter occurs exactly at the place where a pillar is formed; but this is of no consequence, as the shearing or cutting made by the miner ought to be in a line parallel to the backs and cutters. It frequently happens that the dip-head level intersects the cutters in its progress at a very oblique angle. In this case, when rooms and pillars are set off, the face of the pillar and width of the room must be measured off an exact breadth in proportion to the obliquity, as in *fig.* 1508. By neglect of this rule much confusion and irregular work is often produced. It is, moreover, proper to make the first set of pillars next the dip-head level much stronger, even where there is no obliquity, in order to protect that level from being injured by any accidental crush of the strata.

We shall now explain the different systems of working: one of the simplest of which is shown in *fig.* 1509: where A represents the engine-pit; B, the bye-pit; C, D, the dip-head levels, always carried in advance of the rooms; and E, the rise- or crop-gallery, also carried in advance. These galleries not only open out the work for the miners in the coal-bed, but, being in advance, afford sufficient time for any requisite operation, should the mines be obstructed by dykes or hitches. In the example before us, the room or boards are worked from the dip to the crop; the leading rooms, or those most in advance, are on each side of the crop-gallery E; all the other rooms follow in succession, as shown in the figure: consequently, as the rooms advance to the crop, additional rooms are begun at the dip-head level, towards C and D. Should the coal work better in a level-course direction, then the level rooms are next the dip-head level, and the other rooms follow in succession. Hence the rooms are carried to the crop or rise in the one case, till the coal is cropped out, or is no longer workable; and in the other, they are extended as far as the extremity of the dip-head level, which is finally cut off, either by a dyke or slip, or by the boundary of the coal-field.

Fig. 1510 represents a part of a colliery laid out in four panels, according to the improved method of the north of England. To render it as distinct as possible, the line of the boards is at right angles with the dip-head level, or level course of the coal. A is the engine-shaft, divided into three compartments, an engine-pit and two coal-pits, like *fig.* 1493. One of the coal-pits is the down-cast, by which the atmospheric air is drawn down to ventilate the works; the other coal-pit is the up-cast shaft, at whose bottom the furnace for rarefying the air is placed. B C, is the dip-head level; A E, the rise- or crop-gallery; K, K, the panel-walls; F, G, are two panels completed as to the first work; D, is a panel, with the rooms *a, a, a,* in regular progress to the rise; H, is a panel fully worked out, whence nearly all the coal has been extracted: the loss amounting in general to no more than a tenth, instead of a third, or even a half, by the old method. By this plan of Mr. Buddle's also, the pillars of a panel may be worked out at any time most suitable for the economy of the mining operation.

In Mr. Buddle's system the pillars are very large, and the rooms or boards narrow; the pillars being in general 12 yards broad, and 24 yards long; the boards 4 yards wide; and the walls or thirlings cut through the pillars from one board to another, only 5 feet wide, for the purpose of ventilation. In the figure, the rooms are represented as proceeding from the dip to the crop, and the panel-walls act as barriers thrown round the area of the panel to prevent the weight of the superincumbent strata from over-running the adjoining panels. Again, when the *pillars* of a panel are to be worked, one range of pillars, as at I (in H), is first attacked; and, as the workmen cut away the furthest pillars, columns of prop-wood are erected betwixt the pavement and the roof, within a few feet of each other (as shown by the dots), till an area of above 100 yards square is cleared of pillars, presenting a body of strata perhaps 130 fathoms thick, suspended clear and without support, except at the line of the surrounding pillars. This operation is termed working the *goaf*. The only use of the prop-wood is to prevent the stratum, which forms the ceiling over the workmen's heads, from falling down and killing them by its splintery fragments. Experience has proved that before proceeding to take away another set of pillars, it is necessary to allow the last-made goaf to fall. The workmen then begin to draw out the props, which is a most hazardous employment. They begin at the more remote props, and knock them down one after another, retreating quickly under the protection of the remaining props. Meanwhile the roof-stratum begins to break by the sides of the pillars, and falls down in immense pieces; while the workmen still persevere, boldly drawing and retreating till every prop is removed. Nay, should any props be so firmly fixed by the top pressure that they will not give way to the blows of heavy mauls, they are cut through with axes; the workmen making a point of honour to leave not a single prop in the goaf. If any props are left in the goaf it causes an irregular subsidence of the strata, and throws more pressure on the adjacent pillars. The miners next proceed to cut away the pillars nearest to the sides of the goaf, setting prop-wood, then drawing it, and retiring as before, until every panel is removed, excepting small portions of pillars which require to be left under dangerous stones to protect the retreat of the workmen. While this operation is going forward, and the goaf extending, the superincumbent strata, being exposed without support over a large area, break progressively higher up; and when strong beds of sandstone are thus giving way, the noise of the rending rocks is very peculiar and terrific; at one time loud and sharp, at another hollow and deep.

1510



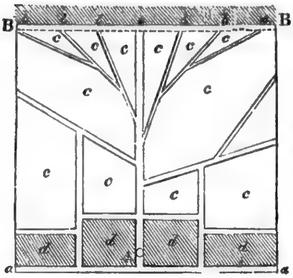
As the pillars of the panels are taken away, the panel-walls are also worked progressively backwards to the pit-bottom; so that only a very small proportion of coal is eventually lost.

The fourth system of working coal is called the *long way*, the long-wall, or the Shropshire and Derbyshire method.

The object of this system is, to begin at the pit-bottom, and to cut away at once every inch of coal progressively forward, and to allow the whole superincumbent strata to crush down behind and over the heads of the workmen. This plan is pursued chiefly with coals that are thin, from 4 to 5 feet being reckoned the most favourable thickness for proceeding with comfort, amidst ordinary circumstances, as to roof, pavement, &c. When a pit is opened on a coal to be treated by this method, the position of the coals above the lowest seam sunk to must first be considered; if the coal-beds be contiguous it will be proper to work the upper one first, and the rest in succession downwards; but if they are 8 fathoms or more apart, with strata of strong texture betwixt them, the working of the lower coals in the first place will do no injury to that of the upper coals, except breaking them, perhaps, a little. In many instances, indeed, by this operation on a lower coal, upper coals are rendered more easily worked.

When the operation is commenced by working on the long-wall plan, the dip-head levels are driven in the usual manner, and very large bottom-pillars are formed, as represented in *fig.* 1511. Along the rise-side of the dip-head level, chains of wall, or long pillars, are also made, from 8 to 10 yards and upwards in breadth, and only mined through occasionally, for the sake of ventilation, or of forming new roads. In other cases no pillars are left upon the rise-side of the level; but, instead of them, buildings of stone are reared, 4 feet broad at the base, and 9 or 10 feet from the deep side of the level. Though the roads are made 9 feet wide at first, they are reduced to half that width after the full pressure of the strata is upon them. Whenever these points are secured, the operation of cutting away the whole body of the coal begins. The place where the coal is removed, is named the *gobb* or waste; and *gobbin*, or gobb-stuff, is stones or rubbish taken away from the coal, pavement, or roof, to fill up that excavation as much as possible, in order to prevent the crush of superincumbent strata from causing heavy falls, or following the workmen too fast in their descent. Coals mined in this manner work most easily according to the way in which the widest backs and cutters are; and therefore, in the Shropshire mode, the walls stand sometimes in one direction, and sometimes in another; the mine always turning out the best coals when the open backs and cutters face the workmen. As roads must be maintained through the gobb or goaf to the working face, pillars of stone, called packs, are formed along each side of the road of several feet in width; and the rock over head along this road is blasted down of sufficient height, so that when the superincumbent strata have sunk, there may be ample height to convey the coals with ponies. In many cases these roads are 6 to 7 feet high, and seldom less than 4 feet. In some coal-fields stone cannot be got in the mine to build the road pillars or packs; but a substitute is found in cord wood, which is formed into a pillar on each side of the road by building it up, and making it as solid as possible with small coal and other small refuse. The pressure of the strata soon makes this a very compact pillar. This method is common in the Leicestershire coal-field.

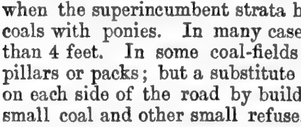
1511



There are two principal modifications of the long-wall plan. The first, or the original system, was to open out the wall round the pit-bottom; and, as the wall face extended, to set off main roads and branches, very like the branches of a tree. These roads were so distributed, that between the ends of any two branches there should be a distance of 30 or 40 yards, as might be most convenient (see *fig.* 1511). Each space of coal betwixt the roads is called a wall; and one half of the coals produced from each wall is carried to the one road, and the other half to the other road. This is a great convenience when the roof is bad; and hence a distance of only 20 yards betwixt the roads is in many instances preferred. In *fig.* 1511, A represents the shaft; B B, the wall-face; *a*, the dip-head level; *b*, the roads, from 20 to 40 yards asunder; *c*, the *gobb* or waste, with buildings along the sides of the roads; and *d*, the pillars.

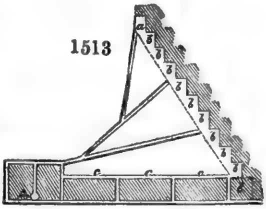
The other plan is represented in *fig.* 1512, where A shows the pit, with the bottom pillars; *b*, the dip-head levels; *c*, the off-break from the level, where no pillars are left; *d*, the off-break, where pillars remain to secure the level. All roads are protected in the sides by stone buildings, if they can be had, laid off 9 feet wide. After the crush settles, the roads generally remain permanently good, and can, in many cases, be travelled through as easily 50 years after they have been made as at the first. Should stones not be forthcoming, coals must be substituted, which are built about 20 inches in the base. In this method, the roads are likewise from 20 to 40 yards apart; but instead of ramifying, they are arranged parallel to each other. The miners secure the waste by gobbing; and three rows of props are carried forwards next the wall faces *a*, with pillars of stone or of coal reared betwixt them. This mode has a more regular appearance than the other; though it is not so generally practised in Shropshire as in Derbyshire.

1512



In the post-and-stall system, each man has his own room, and performs all the labour of it; but in that of Shropshire, there is a division of labour among the workmen, who are generally divided into three companies. The first set curves, holes, or pools the coal along the whole line of walls, laying in or pooling at least 3 feet, and frequently 45 inches, or 5 quarters, as it is called. These men are named *holers*. As the crush is constantly following them, and impending over their heads, causing frequent falls of coal, they plant props of wood for their protection at regular distances in an oblique direction between the pavement and wall face, called *spragging*. Indeed, as a further precaution, staples of coal, about 10 inches square, are left at every 6 or 8 yards, till the line of holing or curving is completed. The walls are then marked off into spaces of from 6 to 8 yards in length; and at each space a shearing or vertical cut is made, as deep as the holing; and when this is done, the holer's work is finished. The set who succeed the holers are called getters. These commence their operations at the centre of the wall divisions, and drive out the *gibbs*, or sprags, and staples. They next set wedges along the roof, and bring down progressively each division of coal; or, if the roof be hard-bound, the coal is blown down with gunpowder. When the roof has a good parting, the coals will frequently fall down the moment the gibbs are struck; which makes the work very easy. The getters are relieved in their turn by the third set, named butty-men, who break down the coals into pieces of a proper size for sending up the shaft, and take charge of turning out the coal from the wall face to the ends of the roads. This being done, they build up the stone pillars, fill up the gobb, set the trees, or props, clear the wall faces of all obstructions, set the gibbs, and make everything clear and open for the holers to resume their work. If the roads are to be heightened by taking down the roof, or removing the pavement, these butty-men do this work also, building forwards the sides of the roads, and securing them with the requisite props. When a coal has a following or roof stone, which regularly separates with the coal, this facilitates the labour, and saves much of the coal; and should a soft bed of fire-clay occur a foot or two beneath the coal-seam, the holing is made in it, instead of into the coal, and the stone betwixt the holing and the coal benched down, which serves for pillars and gobbing. In this way all the vendible coal becomes available.

1513

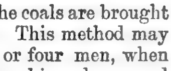


Another form of the Shropshire system is, for each miner to have from 6 to 12 feet of coal before him, with a leading-hand man; and for the several workmen to follow in succession like the steps of a stair. When the coal has open backs and cutters this work goes on very regularly, as represented in *fig.* 1513, where the leading miner is at *a*, next to the outcrop, and *b b*, &c. are the wall faces of each workman; A being the shaft, and B the dip-head level. In this case the roads are carried either progressively through the gobb, or the gobb is entirely shut up; and the whole of the coals are brought down the wall-faces, either to the dip-head level or the road *c c*. This method may be varied by making the walls broad enough to hold two, three, or four men, when each set of miners performs the whole work of holing, getting, breaking down, and carrying off the coals.

It is estimated that from one-eighth to one-twelfth part only of the coals remains underground by the long-wall plan; nay, in favourable circumstances, almost every inch of coal may be taken out, as its principle is to leave no solid pillars nor any coal below, except what may be indispensable for securing the gobb. Indeed, this system might be applied to coal-seams of almost any ordinary thickness, providing stuff to fill up the gobb could be conveniently procured.

When coals do not exceed 20 feet in thickness, and have good roofs, they are sometimes worked as one bed of coal; but if the coal be tender or free, it is worked as two beds. One-half of such thick coal, however, is in general lost in pillars; and it is very seldom that less than one-third can be left. When the coal is free and ready to crumble by the incumbent pressure, as well as by the action of the air, the upper portion of the coal is first worked, then a scaffolding of coal is left, 2 or 3 feet thick, according to the compactness of the coal; and the lower part of the coal is now worked, as shown in *fig.* 1514. As soon as the workings are completed to the proposed extent, the coal scaffoldings are worked away, and as much of the pillars as can be removed with safety. As propwood is of no use in coal-seams of such a height, and as falls from the roof would frequently prove fatal to the miners, it is customary with tender roofs to leave a ceiling of coal from 2 to 3 feet thick. This makes an excellent roof; and should it break, gives warning beforehand, by a peculiar crackling noise, very different from that of roof-stone crushing down.

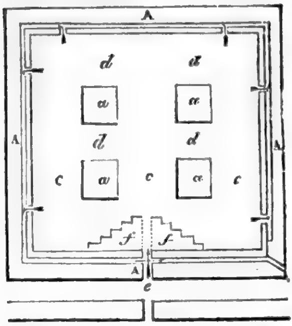
1514



One of the thickest coals in Great Britain, worked as one bed from roof to pavement, is the very remarkable seam near the town of Dudley, known by the name of the Ten-yard coal, about 7 miles long and 4 broad. No similar coal has been found in the island; and the mode of working it is quite peculiar, being a species of panel work, totally different from the modern Newcastle system. A compartment, or panel, formed in working the coal, is called a side of work; and as the whole operation is exhibited in one of these compartments, it will be proper to describe the mode of taking the coal from one of them, before describing the whole extent of the workings of a mine:

Let *fig.* 1515 represent a side of work: A, the ribs or walls of coal left standing, round, constituting the side of work; *a*, the pillars, 8 yards square; *c*, the stalls, 11 yards wide; *d*, the cross openings, or through puts, also 11 yards wide; *e*, the bolt-hole, cut through the rib from the main road, by which bolt-hole the side of work is opened up, and all the coals removed. Two, three, or even four bolt-holes open into a side of work, according to its extent; they are about 8 feet wide and 9 feet high. The working is in a great measure regulated by the natural fissures and joints of the coal-seam; and though it is 30 feet thick, the lower band, of 2 feet 3 inches, is worked first; the miners choosing to confine themselves within this narrow opening, in order to gain the greater advantage afterwards, in working the superjacent coal. Whenever the bolt-hole is cut through, the work is opened up by driving a gallery forward, 4 feet wide, as shown by the dotted lines. At the sides of this gallery next the bolt-hole, each miner breaks off in succession a breast of coal, two yards broad, as at *f f*, by means of which the sides of the rib-walls A, are formed, and the area of the pillars. In this way each collier follows another, as in one of the systems of the Shropshire plan. When the side of work is laid open along the rib-walls, and the faces and sides of the pillars have been formed, the upper coals are then begun to be worked, next the rib-wall. This is done by shearing up to a bed next the bolt-hole, and on each side, whereby the head coals are brought regularly down in large cubical masses, of such thickness as suits with the free partings or subordinate divisions of the coals and bands. Props of wood, or even stone pillars, are placed at convenient distances for the security of the miners.

1515



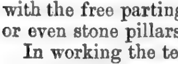
In working the ten-yard coal, a very large proportion of it is left underground, not merely in pillars and rib-walls, but in the state of small coal produced in breaking out the coal. Hence from four-tenths to a half of the total amount is lost for ever.

The thick or ten-yard coal has, however, been worked on the long-wall method by Mr. Gibbons, near Dudley, with great advantage in the yield. He works 12 to 14 feet of the upper part of the seam first; and after allowing the strata to become somewhat consolidated, the lower part is worked, leaving 2 to 3 feet of coal for a roof, some portion of which is picked out of the gobb. About 12 per cent. of the coal is left by this method.

Edge coals, which are nearly perpendicular, are worked in a peculiar manner; for, the collier stands upon the coal, having the roof on the one hand, and the floor on the other, like two vertical walls. The engine-pit is sunk in the most powerful stratum. In some instances the same stratum is so vertical as to be sunk through for the whole depth of the shaft.

Whenever the shaft has descended to the required depth, galleries are driven across the strata from its bottom, till the coals are intersected, as is shown in *fig.* 1516, where we see the edge coals at *a*, *a*; A, the engine-pit; *b*, *b*, the transverse galleries from the bottom of the shaft; and *c*, *c*, upper transverse galleries, for the greater conveniency of working the coal. The principal edge-coal works in Great Britain lie in the neighbourhood of Edinburgh.

1516



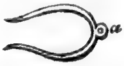
The modes of carrying coals from the point where they are excavated to the pit-bottom, are nearly as diversified as the systems of working.

One method employs hutches, or baskets, having slips or cradle feet shod with iron, containing from 2 to 3 hundred weight of coals. These baskets are dragged along the floor by ropes or leather harness attached to the shoulders of the workmen, who are either the colliers or persons hired on purpose. This method is used in several small collieries; but it is extremely injudicious, exercising the muscular action of a man in the most unprofitable manner. Instead of men, horses are sometimes yoked to these basket-hurdles, which are then made to contain from 4 to 6 hundred weight of coals; but from the magnitude of the friction this plan cannot be commended. This method is now almost entirely extinct.

An improvement on this system, where men draw the coals, is to place the basket or corve on a small four-wheeled carriage, called a tram, or to attach wheels to the corve itself. Thus much more work is performed, provided the floor be hard; but not on a soft pavement, unless some kind of wooden railway be laid.

The transport of coals from the wall-face to the bottom of the shaft was greatly facilitated by the introduction of cast-iron railways, in place of wooden roads, first brought into practice by Mr. John Carr of Sheffield. The rails are called tram-rails, or plate-rails, consisting of a plate from 3 to 4 inches broad, with an edge at right angles to it about two inches and a half high. Each rail is from 3 to 4 feet long, and is fixed either to cross-bearers of iron, called sleepers, or more usually to wooden bearers. In some collieries, the miners, after working out the coals, drag them along these railways to the pit-bottom; but in others, two persons called trammers are employed to transport the coals; the one of whom, in front of the corve, draws with harness; and the other, called the putter, pushes behind. The instant each corve arrives from the wall-face, at a central spot in the system of the railways, it is lifted from the tram by a crane placed there, and placed on a carriage called a rolley, which generally holds two corves. Whenever three or four rolleys are loaded, they are hooked together, and the rolley driver, with his horse, takes them to the bottom of the engine-shaft. The rolley horses have a peculiar kind of shafts, commonly made of iron, named *libers*, the purpose of which is to prevent the carriage from overrunning them. One of these shafts is represented in *fig.* 1517. The hole shown at *a*, passes over an iron peg or stud in front of the rolley, so that the horse may be quickly attached or disengaged. By these arrangements the work is carried on with surprising regularity and despatch. Where the roads are well constructed, a horse will convey a load of 7 to 8 tons on the level.

1517



We shall now describe briefly the modes of working coal dip of or on the deep of the engine-pit bottom. Headings are driven either on the full dip of the mine, or any convenient angle to it, the requisite distance. The water is pumped up these dip headings by the pumping-engine on the surface. A pump-rod or spear passes down the side of the shaft, and is attached to a quadrant at the bottom of the shaft, which quadrant transfers the perpendicular motion of the spears in the shaft to the spears or pump-rods in the dip headings. The quadrant is constructed so that the stroke of the pump in the dip headings can be lengthened or shortened as required.

In level free coals, these pumps may be worked by a water-wheel stationed near the bottom of the pit, impelled by water falling down the shaft, to be discharged by the level to the day (day level).

When the above arrangements are applied for pumping, the coals are drawn from the deep either by horses or an engine placed on the surface.

Where operations are very extensive, some mining engineers place the engine underground for working the dip coal; and it both pumps the water and draws the coal to the bottom of the shaft.

High-pressure engines are employed for this purpose, working at a pressure of from 30 to 50 lbs. per square inch. These machines are quite under command, and, producing much power in little space, they are the most applicable for underground work. An excavation is made for them in the strata and isolated from the coal, and the air used for the furnace under the boiler is the returned air of the mine ventilation if the mine is free from explosive gas. If the mine yields explosive gas, the boiler furnace is supplied with fresh air. In the dip road a double tram-road is laid; so that while a number of loaded corves are ascending, an equal number of empty ones are going down. Although this improved method has been introduced only a few years back, dip workings have been already executed more than an English mile to the dip of the engine-pit bottom in the Newcastle coal-fields. It may hence be inferred, that this mode of working is susceptible of most extensive application; and in place of sinking pits of excessive depth upon the dip of the coal, at an almost ruinous expense, much of the dip coal will in future be worked by means of the pits sunk on the rise. In the Newcastle district, coals are now working in an engine-pit 115 fathoms deep, and dip of the engine-pit bottom, above 1,600 yards, and fully 80 fathoms of perpendicular depth more than the bottom of the pit.

The deep pit in Dukinfield is 2,004 feet below the surface to the point where it intersects the Black Mine coal-seam, which is 4 feet 6 inches thick, and of the best quality for domestic and manufacturing purposes—and a further depth of 500 feet has been attained by means of an engine-plane in the bed of coal, which dips at an angle of 27°, so that a great portion of the coal is now worked there at the depth of 2,504 feet below the surface.

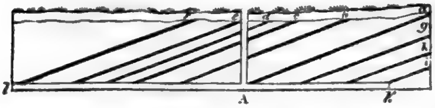
The shafts at Pendleton are 1,635 feet deep, and in like manner a further depth has been reached of about 500 feet, amounting in the aggregate to 2,135 feet, at which point a large quantity of coal is daily worked.

The Rose Bridge Pits near Wigan intersect the cannel at 1,773 feet below the surface—which varies in thickness from 2 feet 8 inches to 3 feet, and is of excellent quality.

At the most extensive collieries in the north of England, engine-power is not only applied for the transit of coals from the dip, but along the main level roads of the mine, by means of endless wire ropes. The economy of steam-power has superseded horses at many collieries. Steam-power can only be applied with advantage where large quantities of coal have to be removed.

If an engine-pit be sunk to a given coal at a certain depth, all the other coals of the coal-field, both above and below the coal sunk to, can be drained and worked to the same depth by driving a level cross-cut mine, both to the dip and rise, till all the coals are intersected, as represented in *fig.* 1518, where A is the engine-pit bottom

1518



reaching to the coal *a*; and *b*, *c*, *d*, *e*, *f*, coals lying above the coal *a*; the coals which lie below it, *g*, *h*, *i*; *k* is the forehead of the cross-cut mine, intersecting all the lower coals; and *l*, the other forehead of the mine, intersecting all the upper coals.

MINIUM. Red oxide of lead, obtained by roasting metallic lead or its carbonate.

MINT (Saxon *mynet*, money or stamped coin; Danish *munt*, *mint*, coin. The word 'mint' is doubtless a derivative from *mine*, or, Latin, *moneta*, from the same root). The place where money is coined by public authority.

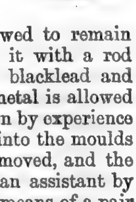
Minting or coining is the term applied to the processes employed in the manufacture of money. It is proposed to describe the present mode of manufacture; but it may be as well to state, that in remote periods money was made by cutting out a piece of metal somewhat of the form of the intended coin, and imparting the device to it by the blow of a sledge-hammer. For this purpose the blank piece of metal was laid upon a die, say the obverse, fixed into a block of wood or stone, supposed to have been so large as to absorb the vibration caused by the blow, and to a great extent prevent the quivering which would naturally arise, and cause unsteadiness. The workman then took the other die, say the reverse, and passing it through a folded sheet of lead, in order to avoid the shock to the hand, he placed the engraved part on the blank, which was resting on the lower die, and held it firmly while another workman struck it with a sledge-hammer. It is worthy of remark that a piece of lead such as that described is in the Museum of Dies at the Royal Mint; and although its surface, by the action of the atmosphere and other causes, is now converted into carbonate of lead, indentations caused by the tips of the workman's fingers are evident. This piece is believed to have been used with a die of Edward IV. At a later period the upper die was held in a twisted hazel stick. After each blow the dies were what is technically termed locked together; that is, the lower and upper dies were made to fit into the partly-formed coin, so that neither die could turn without turning the whole mass, and then a second or third blow was given, till the coin was completed. An improvement on this method was effected by fitting the two dies into rods of iron, which may be represented as a pair of tongs; the flat parts which are used to take a coal would then show the position occupied by the dies. This plan saved the operator some risk of bruised fingers, but the process was essentially the same as the original one; and to money produced by either means was applied the term *hammered* money, in contradistinction to *milled* money; that is, money which was made from blanks obtained from fillets which had been rolled in a very rough kind of rolling mill, driven by horse-power—the germ from which sprang the present machinery. On this point it is perhaps of interest to quote a passage from the Report made to the Lords of the Treasury in 1695 by Mr. William Lowndes, who says:—'All the moneys we have now in England, both gold and silver, are reducible to two sorts, one stamped with the hammer, and the other pressed with an engine called the mill. The gold or silver of the hammered money is first cast from the melting-pot into long bars, those bars are cut with shears into several square pieces of exact weight for sovereigns, angels, crowns, half-crowns, shillings, &c. Then with tongs and hammer they are forged into a round shape, after which they are blanched (that is, made white or refulgent by nealing or boiling), and afterwards stampt or impressed with an hammer to make them perfect money. This method of making money with the hammer (as appears in the said red book) was practised in the reign of King Edward the First' [the book referred to is in the Exchequer] . . . 'and this kind of hammered money continued through all the reigns of succeeding Kings and Queens till about the year of our Lord 1663, when by several warrants and command of the King, Charles the Second: to wit, by one warrant, dated the fifth of November 1662; one warrant, dated the eighth of April 1663; and a third warrant, dated the twenty-fourth of December 1663; the other sort, called *milled money*, was first fabricated to be current in England in this manner: first, the gold or silver is cast out of the melting-pot into long flat bars, which bars are drawn through a mill (wrought by a horse), to produce the just thickness of guineas, half-guineas, crowns, half-crowns, shillings, &c. Then with forcible engines called *cutters*, which answer exactly to the respective sizes or dimensions of the money to be made, the round pieces are cut out from the flat bar, shaped as aforesaid (the residue whereof, called sizel, is melted again), and then every piece is weighed and made to agree exactly with the intended weight, and afterwards carried to other engines (wrought secretly), which put the letters upon the edges of the larger silver pieces, and mark the edges of the rest with a graining. The next thing is the blanching, performed as above; and at last every piece is brought to the press, which is called the *mill* (wrought of the strength of men), and there receives the impression, which makes it perfect *milled* money.'

The processes now used are as elaborate as the old methods were simple; but considering the requirements of the present day, and the enormous quantity of money produced, it must not be expected that our coins will, for depth of engraving, bear comparison with those of the Romans, who, though succeeding in producing finished works of art, seem to have forgotten the wear and tear to which they would be subjected, and so left them, as a rule, free from a protecting edge; hence they would lose their image and superscription at a far earlier date from their birth or manufacture than would well-made coins of the present period.

It was formerly believed that gold could be sent to the Mint to be coined free of charge to the importer; such, however, was not the case. By the Act 33 Vict. cap. 10, several Acts relating to the coinage were repealed, and all persons obtained the right to send gold to the Mint on certain specified conditions. The standard for gold coin is fixed, by the Act now referred to, at 'twenty-two carats fine and two carats of alloy in the pound weight Troy.' The same that has obtained since 18th Charles II. Silver is also maintained at the former standard, 'eleven ounces two pennyweights fine silver and eighteen pennyweights of alloy in every pound weight Troy.' The Bank of England is practically the only 'importer' of bullion to the Mint, and by coinage makes a considerable profit merely from its exceptional circumstances; but for full details, we refer the reader to Ansell's 'Royal Mint,' (3rd edition, Effingham Wilson), where will be found elaborate discussions upon the various modes of proceeding, as well as on the loss and gain in the different operations: subjects which are manifestly unfitted for this work.

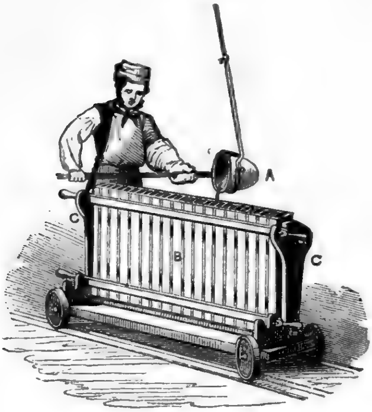
When the authorities of the Bank of England desire to coin gold they send at stated intervals 'importations' of 200 or 300 ingots, each weighing about 180 ounces Troy, and previously assayed. Upon arrival at the Mint these ingots are again weighed and assayed, and in accordance with the amount of gold they contain they are alloyed with copper or enriched by the addition of fine gold, to bring them to the fineness of standard or crown gold, so that each coin when formed shall contain 22 parts of pure gold and 2 parts of alloy. The ingots having been thus 'potted' or rated are taken to the melting-house, where their individuality is finally lost, for it is here that they are formed into bars for coining.

1519

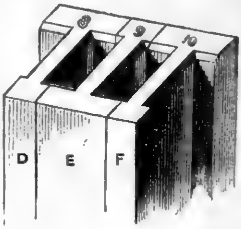


In the Mint there are many furnaces; each furnace being 12 inches square, and 24 inches deep to the top of the bars. The melting of the gold is effected in a plumbago crucible, A, shown in *fig.* 1519. It is 9½ inches deep, and 7 inches across the top of the inside. The pot previously annealed is placed on a bottom which stands upon the two centre fire-bars. The bottom is intended to protect the base of the pot A from the stream of air which is necessary to the combustion of the fuel, but which would destroy the pot. The pot is then covered by its muffle, B, and lid C, and surrounded by fuel, which, as it burns up, warms and then heats the pot to redness, but so gradually that there is no great risk of breaking the pot. When the pot has become of a full red heat the ingots are carefully placed in it, and the alloy added by means of a funnel to prevent any being thrown on one side; the pot is then covered up and allowed to remain till the whole mass of metal has liquefied. The foreman then stirs it with a rod made of the same substance as the pot, which is a compound of blacklead and Stourbridge clay, and is fully described under CRUCIBLE. The fluid metal is allowed to remain in the furnace till it has acquired a peculiar appearance, known by experience as indicating the temperature to be such that the metal when poured into the moulds will produce solid and workable bars. At this point the firing is removed, and the lid and muffle taken from the pot, which is lifted from the furnace by an assistant by a hand crane. The foreman then conveys the pot with its contents by means of a pair of tongs, which clamp it to the frame of moulds, when his assistant brings forward a loop of iron, suspended by a chain and cord from the ceiling, and passing the loop of iron over a button on the end of the tongs, as shown at A, *fig.* 1520, supports the weight of the pot, and regulates its height, while the foreman pours the metal into the moulds, B, fixed in the frame, C, which runs on wheels in a tramway. Three pieces of planed iron form two moulds, as shown in *fig.* 1521, where D^8,E^9,F^{10}, show the form of these planed pieces, and the manner of placing them together. The bars are solidified immediately, and when all the moulds have been filled, they are taken to pieces, and the bars plunged into cold water, as in the case of silver, to be described. From the bars obtained from each pot, two pieces are cut off for assaying, by the assayers, the bars being numbered according to the pot from which they were poured, and lettered distinctively, according to the day on which they were melted. Should the assay prove unsatisfactory, the metal is adjusted and re-melted. If the assays are satisfactory, the bars are forwarded to the coining department.

1520



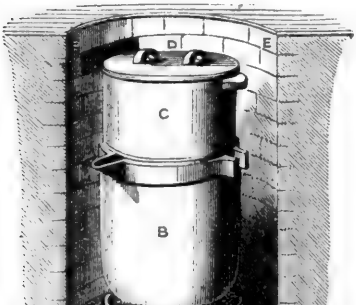
1521



Previously to melting, pieces of charcoal are placed at the bottom of the pot for the purpose of reducing any oxide that may be present in the alloy, because oxide of copper renders some kinds of gold perfectly brittle and unworkable. In order to prevent this charcoal from falling into the moulds with the gold the assistant holds a piece of stick at the mouth of the pot, thus allowing the gold to flow while he detains the charcoal.

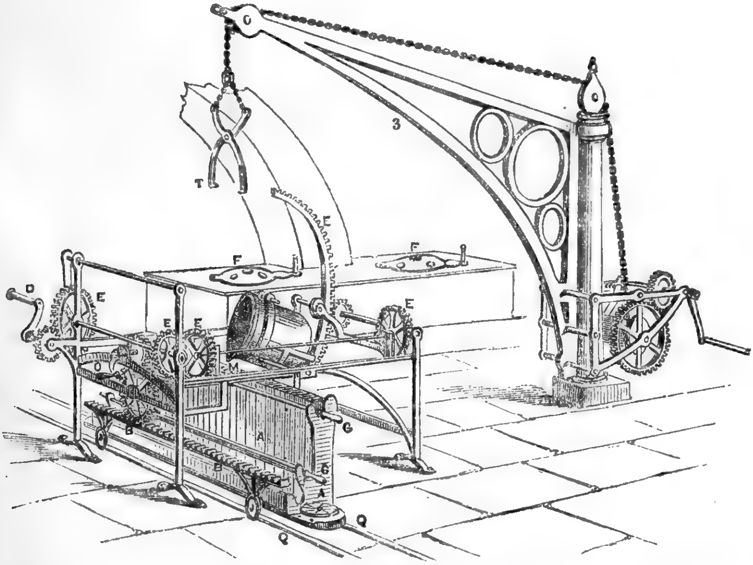
Silver is bought, through the brokers, by the Master of the Mint, either in the form of foreign coin (5-franc pieces are preferred) or ingots; and to the silver so obtained is added so much copper or pure silver as shall bring the whole mass up to the standard silver of the realm, which consists of 220 parts of silver and 18 parts of copper. The metal so arranged is weighed out into charges of about 4,000 ounces for the wrought-iron (plumbago is now used) melting-pot, which is represented in *fig.* 1522, as seen in the furnace E, standing on the 'bottom,' A, which rests on the fire-bars, and is made partially cup-shaped, and filled with powdered coke, that the bottom of the pot, B, may be perfectly supported, while at the same time it is protected from the current of air which is supplied to the furnace. Powdered coke, being a bad conductor, prevents the free passage of heat from the base of the pot to the 'bottom,' and the consequent probable fusion of the two through the agency of the oxide of iron, which forms and accumulates whenever iron is repeatedly heated. D is the lid of the pot; and C, the muffle or funnel, against the sides of which the metal rests during the process of fusion, to prevent its falling over into the burning coke. The pot, when

1522



charged, is allowed to remain in the furnace till the metal has fused, and the temperature has risen to a point little short of that which would so far soften the wrought-iron pot as to cause it to lose its shape. The pot is lifted by the tongs, T, of the crane, 3, from the furnace, F, *fig.* 1523, (after the fire has been removed by displacing some of the fire-bars), swung round and dropped into the cradle, M, when it is secured by a screw, which draws tight the band at the top. The melted silver is then thoroughly stirred with an iron rod; and, all being ready, the frame of moulds, A, is run under the cradle-stand so far as to allow the rack, B, to work into the wheel N. The foreman then, by means of the handle D, which communicates by E with the cradle in which the pot is fixed, raises the pot, and tilts it so much as is necessary to pour the fluid silver into the mould until it is filled; he then lowers the pot, and waits while an assistant by the handle O, connected with the cogwheel N, moves the moulds forward as they are required to be filled. The moulds are ranged side by side in the frame, and pressed firmly together by screws at the ends of the mould-frames, and secured in front by two bars of iron, G, which fit into wedge-shaped grooves, slanting forwards.

1523



The metal solidifies immediately, and the pot having been emptied, the carriage of moulds is run on its wheels, Q, from under the cradle-frame, and the screws having been loosened, the moulds are caused to fall to pieces, and each bar as it is exposed is taken by tongs and plunged into cold water, as much to save time as to soften and case-harden the bar by sudden cooling. The bars produced from the whole pot of metal are numbered with a distinctive figure to designate the pot, and with two letters to indicate the day's melting; assay-pieces are then cut from the first, middle, and last bars of the set.

The bars for different denominations of coins are proportioned in width so as to admit of two rows of blanks being cut from the fillets produced from them. Space, however, hardly admits of our giving detailed measurements; but it may be expected that a uniform thickness of ½ an inch will at last be adopted by the Mint authorities for all bars, both of gold and silver, as they now admit the advantage of using ½-inch bars for the gold coinage.

The 'assay-pieces' are assayed to determine that they contain the proportion of gold or of silver required by law, and it is assumed that these pieces give a fair average of the bars; hence, that the coin produced will be accurate. For a full description of the processes adopted, see GOLD; but it should be here noticed that the operation has been much simplified by the improvements to which we now invite attention.

Messrs. Johnson, Matthey, and Co. have invented a tray of platinum capsules or thimbles, into which the assay-pieces are placed for treatment with acid, instead of into the ordinary glass vessels over gas-burners. The advantages of this invention are too manifest to require elaboration; but saving of acid, gas, labour, and risk of error are amongst the chief of them; and, besides, the plan has been in successful operation in their own assay offices in Hatton Garden, as well as in other important assay offices, for several years past. The first cost would seem to be the principal objection to this plan of Messrs. Johnson, Matthey, and Co.; but this is really a small matter, for the apparatus becomes stock-in-trade, and its cost should be viewed simply as so much capital, whose interest is paid by the saving effected in glass, but more especially by the smaller amount of acid actually employed, while the platinum can at all times be sold, for nearly its original cost, as old metal.

The mode of operation is as follows:—A stand of slate is so arranged that a means of heating is made to rest on its base. For this purpose a jet of gas is preferred; where, however, gas cannot be obtained, an ordinary oil lamp or a charcoal fire may be used. On a shelf over the source of heat are placed two or three receptacles of platinum, each communicating with a vessel made of porcelain, provided with three necks and an overflow-pipe. There is a kind of sieve or tray of platinum, so arranged as to carry from 16 to 100 thimbles of platinum, and provided with a handle, so that this tray, with its charge, can be manipulated at pleasure. The thimbles vary in size according to taste, but each one is slit or cut at the bottom, so that the solution of silver as it is formed may by its density fall out, and allow the clean acid to take its place.

When an operation is to be performed, the tray filled with the charged thimbles—that is, containing the assay-pieces—is placed in one of the platinum receptacles or boilers, and heated to a fitting temperature; when the desired effect is produced, the tray is lifted into another receptacle, and again heated; this may be carried to three times if necessary. The products of decomposition of the acid go, with the acid which evaporates, into the porcelain vessel, where the free acid falls through the overflow-pipe into a proper chamber, while the acid fumes pass into the flue through the third neck before spoken of. The parted assays having been washed by several immersions in boiling distilled water, without removal from their thimbles, have now to be dried and annealed in a platinum muffle, so formed as to fit into an ordinary muffle, and, after annealing, to be weighed in the usual manner, having saved at least 75 per cent. of the usual trouble.

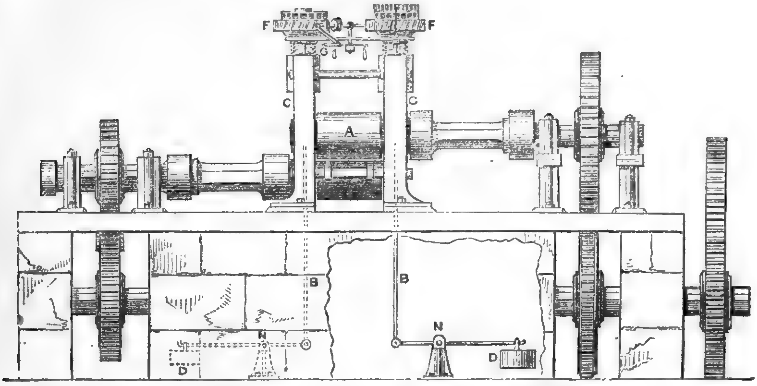
It is almost needless to add that the system of *proofs* must be used with this process.

The assay for silver is not so tedious, as it is finished at the point where it leaves the muffle on the cupel; but up to this point it passes through precisely the same process as the gold.

The Master of the Mint, on receipt of the assay reports, determines if the metal has been found within the limits, or remedy allowed for error; and, if he be satisfied, signs the reports, and thus enables the bars to be forwarded for coining. And from this point gold and silver undergo nearly the same operations; to follow, then, the practice used for sovereign-bars will suffice for all.

The sovereign-bars having been weighed by the officer, and given by him to his men, are wrought in sets of twenty; each set is called a *batch*, and each bar in the batch undergoes precisely the same process. The bar is passed into an opening of the breaking-down mill, *fig.* 1524, where it receives a considerable compression, for the rollers A, seizing its end, drag it forward, while they roll back and retard the progress of that part of the bar which is not between them. The result is that the bar is lengthened, but not widened materially, so that length is gained at the expense of the thickness, which is regulated by the distance between the rollers. The rollers are driven by shafts and adjusting-couplings, which are themselves driven by the geared wheels. The distance between the rollers is determined by the action of the lever G, which, by the endless wheels on its axle fitting into geared wheels, gives motion to powerful screws shown at F, which terminate in cups on the upper part of the upper brasses of the rollers A, as may be seen at C. The upper brasses are kept always against the ends of the screws by weights, D, which are beneath the mill, but from which levers and rods, B, terminate at the lower part of the upper brasses, at about the position indicated by dotted lines, so that the upper roller has motion either upwards or downwards at pleasure, but the motion upwards is arrested by the powerful screw F, and this point once determined by the reading of a scale, is fixed by the clamp near G. The thickness, therefore, of each bar in a batch is determined within certain limits; and, when each bar in the batch has been rolled, the mill is altered, refixed, and again the rolling goes on till each bar has passed several times, at varying pinches, through these rollers. Owing to the wear of the moulds in which the bars are cast—and which is largely due to the presence of minute portions of antimony in the gold—the bars are never of uniform thickness; hence bars of every denomination are passed through the rollers on their edge, so as to reduce them to one uniform thickness, otherwise the fillets resulting would be ragged, and of unequal widths, which defect would cause them to produce blanks out of *remedy* as to weight.

1524

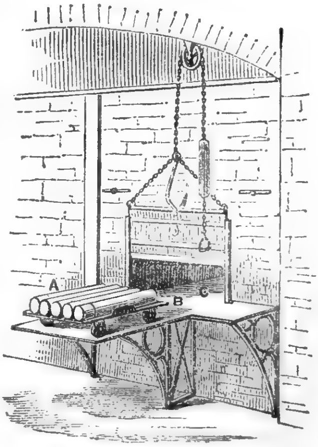


When the metal is poured into the moulds, it almost immediately solidifies, and while solidification is going on contracts in volume, leaving a kind of cup of metal, or hollow part, on the top of the bar. In the act of rolling, the bar maintains an equable width until this hollow part is reached, when it suddenly expands, and at this point the workman shears off the defective part of the bar, because it would ultimately cause dumb works. This operation is now performed in the melting-house, before the bar is rolled, thus saving labour and loss of metal.

The shears may be regarded as large scissors, driven by a drum on the same shaft that carries the driving-wheel for D. The drum is excentric, so that at each revolution the shears are caused to open and shut.

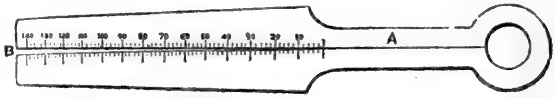
The sheared bars for half-sovereigns are placed in copper tubes, the tops of which are luted on with clay. It is imperative that the copper tubes should be made without solder, because this fuses at a temperature below that which is required to anneal the gold; if present it would run down upon the hot gold, and cause it to fuse and alloy with the solder, thus spoiling the work and entailing expense upon the coiner. The tubes which were used in the Royal Mint were made by Messrs. Benhams and Froud, of Chandos Street, Strand, who, after considerable pains, arrived at a method of making the tubes in such a manner as to entirely satisfy the requirements of the Mint. The tubes, A, are placed on an iron carriage, B, which is then run into the furnace, as shown in *fig.* 1525. The door of the furnace, C, is closed by raising the counterpoise; the heat of the furnace is regulated by a damper. After remaining in this furnace for twenty minutes, the carriage is withdrawn, and the tubes, taken with tongs, are plunged into cold water, to cool the gold as rapidly as possible. The rapid cooling of gold and silver gives to each metal a peculiar character, which is of value in the after processes, and prevents the access of the atmosphere, which, in prolonged cooling, would cause the oxidation and consequent removal of so much copper that the alloyed metal would become too rich in gold for circulation as coin. After annealing, the bars, which are now called *fillets*, go again to the breaking-down mill, through which they are

1525



passed twice, and are then submitted to another pinch without altering the scale at all; so that what is called a *spring-pinch* is given, with the intention of effecting the reduction of the fillet to one uniform thickness, for the breaking down and subsequent rolling cause the fillets to become much thicker in their middle than at their sides. The widening of the fillet is very trifling; but width may be gained to any desired extent at the will of the workman if the bars be submitted to a heavy pinch instead of a series of light ones. The fillet having been submitted to the fourth spring-pinch, is gauged on its side by a steel instrument, of which *fig.* 1526 is a representation. It is a hollow wedge, which is graduated to the thousandth of an inch.

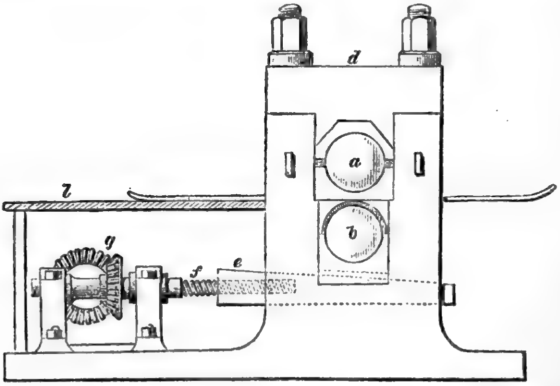
1526



Supposing that the opening from A to B were extended until it were one inch wide at A, the space would be divided between it and B into 1,000 parts, and then every fillet passed into this opening would stop at a given point, say for instance, at 140; such being the case, every part of the same fillet should be arrested precisely at the same point. The fillets are reduced till they measure 117 on this gauge, and are consequently 0·117 inch thick. They are then passed to the next mill, and then to a third mill, where they receive very light pinches. They then pass to another mill, still finer than any of the preceding, and here are submitted to very light pinches, by which they are reduced to 0·058 inch, and are finally finished at the sixth or gauging mill, where they receive three pinches, and are then 0·053 inch thick.

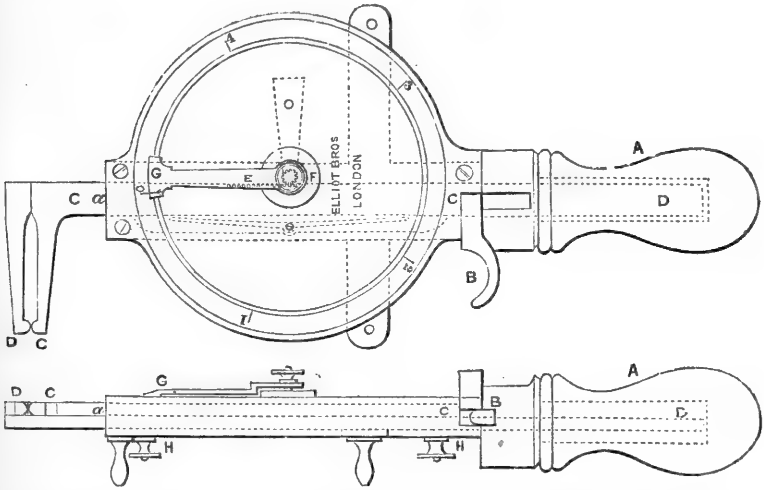
The gauging mill is of different construction from the other mills, as may be seen by reference to *fig.* 1527, where the rollers, *a*, *b*, are seen in the act of reducing a fillet. The upper roller is fixed in brasses loosely clamped together; the upper brass, B, being firmly bolted to the main frame of the mill by screws, while the lower one, which carries the weight of the roller when it is running empty, is supported by spiral springs not shown. The lower roller works on a brass, which rests on a wedge shown at *e*; the brass being cut to fit the wedge, so that it may become similar to a solid mass, irrespective of any motion given to the wedge. By this mode of adjusting, a difference of the 0·001 of an inch may be made with ease between the distance of the rollers, and consequently in the thickness of fillets which may pass between them. The wedge *e* is moved forward and backward by the screw *f*, which itself has motion from the gear work, *g*. Directly a fillet is passed between the rollers, the topmost one is forced against its upper brasses, and further upward motion becomes impossible. As the gauger of fillets requires other tests besides that of the thickness of the edge of the fillet, he punches out a blank from an occasional fillet by a hand-press; the blank falling through the bolster of the cutter is caught, and is then weighed in the hand scales against a standard weight, from which it must not vary more than 0·50 grain. He has, in addition to the gauge represented by *fig.* 1526, one of great accuracy, by

1527



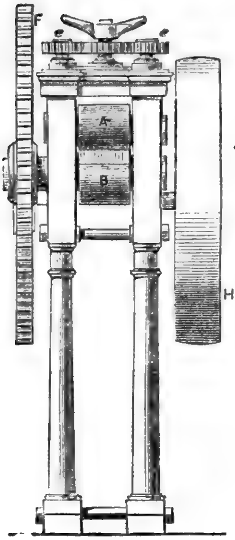
which to measure the fillets at any point, as to width and thickness. This gauge will be more intelligible by reference to *fig.* 1528. A is the handle, which is hollow; B is a lever attached to the flat rod of copper C, which at E is cut with a rack, into which a pinion, F, is made to work. The pinion, F, works on a shaft, the upper end of which carries a hand provided with a vernier, G. If now the handle, A, be firmly held by the hand, while the thumb be made to press the lever, B, towards the end of the handle, the rod, C, is set in motion, and causes the vernier, G, to travel over the dial-plate. The rod, C, rests on another rod, D, made of steel, and so long as to pass into the handle of the instrument. The ends of the rods, C and D, are fitted at *a* with steel shoulders, and are then continued, as represented. If it be desired to measure the thickness of a fillet, the points are caused to open by pressure applied to B, and the fillet is placed between them, when a spring brings back the rod, C, as soon as B is gently released, and encloses the fillet. The separation of the points by the fillet causes the hand or indicator, G, to stand at a point from zero, which is then read. The scale is divided into 500 parts; and if the points be opened 0·50 inch, the hand makes one revolution; so that the ·001 of an inch is gained by one reading. But each 0·001 is subdivided by the vernier into ten, so that a ten-thousandth part of an inch is read without trouble. To measure the diameter of a blank coin, or the width of a fillet, it must be placed between the points; but since the extreme graduation of this gauge is 0·50 inch, it is necessary if it be desired to measure a larger diameter, to press back the lever, B, till the zero of the vernier, G, reaches 0·500 on the scale, and hold it there while a clamp is made fast at the spot indicated by *a*, to prevent the motion of C without D. When the clamp is fixed, the rod, D, must be drawn out till the zero of the vernier reaches that of the scale, when the screws, H, must be tightened to retain D in its new position, with half an inch permanent opening between the points. In a new measurement, that permanent 0·500 must be added to the reading. This arrangement admits of measuring up to 3·5000 inches, to which limit the gauge is extremely accurate. The instrument was invented by Mr. G. F. Ansell, because he found it difficult to convince the men that the fillet was thickest in its middle, and consequently heavier there than it should be; and the production of this instrument at once overcame all those difficulties.

1528

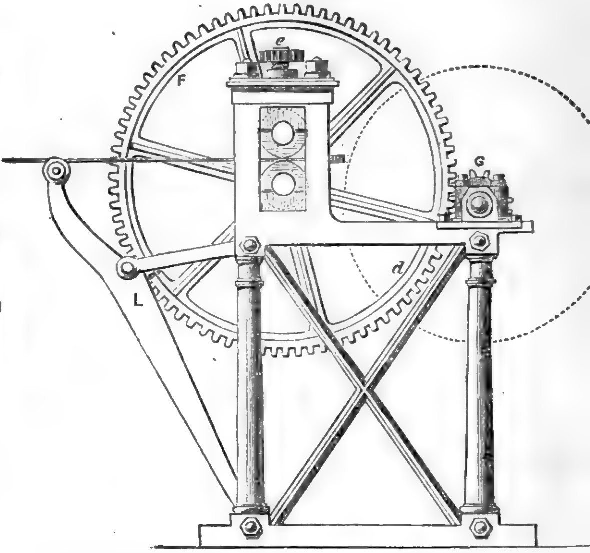


The fillets are weighed from the rolling-room to the drag-room, where they are finally adjusted; for with every energy, discretion, and skill, *fillets cannot be obtained of uniform thickness by simple rolling.* In the drag-room the fillets are taken to the small shears, by which one end of each fillet is trimmed so as to render it square. The fillets having been trimmed so as to render their ends square, are next passed to the extent of about two inches between the rollers of a flatting mill, shown in *figs.* 1529, 1530, 1531, which reduce that part of the fillet to about two-thirds its thickness. A B represent a pair of small rollers, the upper one of which is cut with three flat faces, so that it has three rounding and three flat surfaces; hence, when both rollers are revolving, there are spaces with openings between them; but when the rounding faces come down, those openings are much narrowed, so that any fillet placed between them becomes thinned to just such an extent as may be deemed necessary.

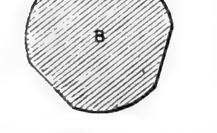
1529



1530



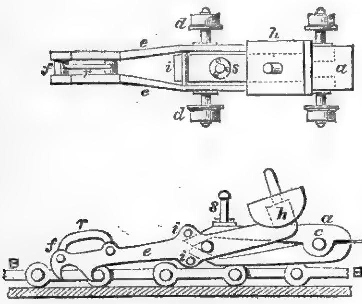
1531



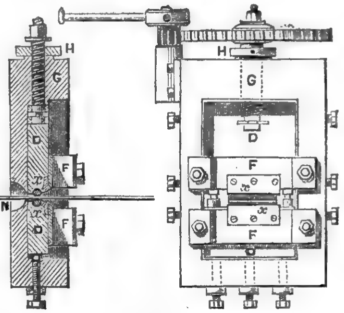
The rollers travel in opposite directions, so as to cause the expulsion of a fillet placed between them. The fillets are rested on L while being *flatted*, and are, after flatting, placed in a trough, from which they are taken to a rolling-mill in the drag-room, of precisely the same construction as that exhibited at *fig.* 1527, to be passed twice through at equal pinches, with a view to render them still more accurate than they were when leaving the rolling-room, as well as to reduce them to the exact thickness at which the tryer has found they will produce the best work at the draw-bench, to which they are now taken for final adjustment. The rolling-mill in the drag-room was provided with steel rollers, which have been wisely abandoned.

Figs. 1532, 1533, represent the head of the *draw-bench*, the name of which is retained, as being in fact its only appropriate one. The *flatted* end of each fillet is passed into the opening shown. The *dog*, *fig.* 1532, is then run up till its teeth seize the fillet. The lever is depressed until one of the hooks, *f*, catches a bar of the circulating chain, B, which in its onward motion drags the dog, and causes it to bite the fillet and *draw* it through the opening at which it has been entered. B gets its motion from a notched cam, the axle of which is shown at O. There are two distinct chains to each draw-bench, and there are two distinct draw-benches, so that one description does for both double ones. C is a cogged wheel, the shaft of which, O, carries two notched drums, and each drum gives motion to a chain, so that both chains travel at the same pace. C is set in motion by the pinion, D, on the shaft which is driven by the wheel E, *fig.* 1534. E is driven by H, which is on the shaft driven by the strap and drums G. *Fig.* 1533 is a representation of the head of the draw-bench, and in studying this engraving it will be well to refer at the same time to *fig.* 1532. The dog takes its name from its resemblance to the head of a bull-dog. It consists of a pair of levers, whose long arms extend beyond the axle-tree of the wheels *d*, and whose shortest arms are formed by the passing of the other axle-tree through the lever. The teeth are set at the front of the short arms. The axle-tree near *d* is fixed to the bars forming *e*, *f*, and runs loosely between the long arms of the lever, so that when *e*, *f* is pulled forcibly it causes the axle-tree to open the long end of the levers, and thereby to close the short end or teeth of the dog, the more rigidly in proportion to the pressure exerted. Directly the fillet has passed through the cylinders, the dog springs slightly by the elasticity of the fillet, and thus releases itself from the chain B; at the instant of release the weight, *h*, over the foremost wheels falls, and by its fall lifts the hooks *f* so high as to admit of their escaping contact with the circulating chain B. The position of the teeth of the dog is shown between *x*, *x*, in *fig.* 1533.

1532

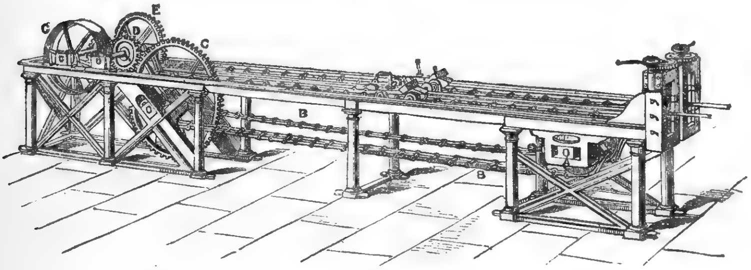


1533



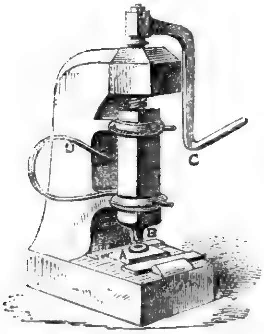
The flatted part of the fillet is just so thin as to admit of its passing easily between the cylinders until seized by the dog, but the part which is not thinned comes against the cylinders, X, and requires considerable force to drag it between them. The cylinders do not rotate; in fact, they may be considered as forming part of a solid mass. As the cylinder wears, the screws of F may be loosened to permit the shifting of the abraded part, so that the whole circumference of the cylinder may be used. The lower cylinder is laid on the bed D, and is clamped there by a cheek fastened on to F by three screws, the holes for which are shown on *x*; the upper cylinder is fixed to the mass, D, by a precisely similar arrangement. The beds C, D, are held perpendicularly by the points of the screws E; and we may now view the cylinders as secured to, and forming part of, their beds. The distance between the cylinders is regulated by the capstans, H, which separate the beds of the cylinders, and so separate the cylinders.

1534



The accuracy of this adjustment is all-important, because the distance between the cylinders determines the thickness of the fillet which passes between them. The bed, D, of the upper cylinder is required to be moveable at pleasure; it is therefore provided with four wedges, two of which, *c*, *c*, are cut so that if looked upon from the top a round hole shows itself, and through this hole the end of the screw G, which at this point, L, is plain, and has a neck turned in it, passes, with its head beneath the wedges and against the upper D. So soon as this is effected the wedges A, B, are pressed into their places, and these holding *c c* together, cause them to secure G by its neck; if, therefore, G be now caused to rise, the block D must rise with it, but the head of this screw rests on the solid block D, while its neck is just so long as to admit of this without itself being pressed against the wedges *c*, *c*. G is a very fine-cut screw, which fits into a female-screw cut in the frame of the head of the draw-bench; it is moved to any distance varying from the 100,000th part of an inch (0·00001) and upwards by the wheel H, which receives a very minute motion from the pinion P by means of a lever, O, fitting into the capstan-head H. K was originally intended to be used to set or fix the screw G when it had been brought to its proper position, but it is not used; for, in fact, the cylinders wear away appreciably by the passage of the fillets, so that they constantly require to be brought nearer together to make up for this wear. With some species of gold the friction is so great that, although oil is used, the cylinders become so hot as to render the gold pasty; in such case a kind of welding takes place, which causes the tearing of the fillet. If this extreme point be not reached, as indeed it seldom is, the cylinders become of varying temperatures, and so great is the effect of this that, in order to compensate for it, the upper cylinder has to be continually raised or depressed. The beds which carry the cylinders become worn by the strain and fret, and require grinding out at intervals; therefore, to allow for the difference which this would make, screws, N, are provided, by which the cylinder in the lower bed can always be raised to its proper position. We cannot but admire the ingenious productions of inventive minds; and surely, if ever there were a marvellous machine for assisting the coiner, it is this; indeed, it may be doubted whether a more admirable instrument for its purpose can be contrived. Sir John Barton, who invented and directed the making of it, took into consideration every circumstance which could possibly arise, but he never saw practically the full advantage of his conception. There are some persons who smile at the draw-bench, but it is one of those inventions which will outlive its detractors, at least so long as economy and perfection are points to be studied in coining. Foreign mints are said to have found no advantage in the use of the draw-bench. It is to be regretted that this instrument has not yet been efficiently used. Mr. J. Martin, of the Paris Mint, has recently made some very accurate experiments with the draw-bench, and has produced results every way in accordance with those obtained by Mr. Ansell in the Royal Mint, and is convinced that the draw-bench may be considered as the coiner's right hand.

1535



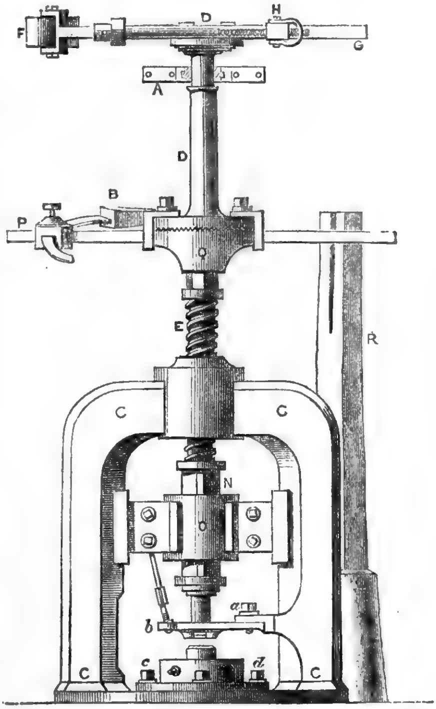
When the fillets have passed between the cylinders of the draw-bench, they are sheared into four lengths by a pair of hand-shears affixed to the bench, and the pieces passed on to the tryer who, by a hand cutting-out press, shown at *fig.* 1535, punches out one or more blanks from each piece of fillet, and weighs it in a delicate balance, placed close beside him, that he may judge if the fillet be likely to produce good blanks. The fillet is placed for this purpose on the bolster, A, and is held in the left hand, while with the right he seizes the handle, C, and pulls it suddenly towards him, when its motion causes a screw with which it is provided to depress the cutter, B, which cuts a blank and pushes it through A, the tryer at the same moment placing his hand under the bench to catch the blank as it falls. The spring, D, is so powerful as to carry back the handle to its original position while the tryer is catching the falling blank.

The fillets, notwithstanding the draw-bench, cannot be brought to perfect accuracy; and, to meet such variations as arise, a difference is made in two of the cutting-out punches, by altering their diameters to such an extent, that a blank cut by them from a standard fillet would vary in weight from a blank cut by them from an ordinary fillet. One cutting-out punch is so altered that a blank would be 0·125 grain, and the other that a blank would be 0·250 grain heavier. This admits of a fillet otherwise too thin being used; but if the fillet be found to err on the other side, it is passed once more either through the draw-bench, or through the mill at a spring-pinch. The tryer should be selected as a peculiarly steady man, possessing a calm judgment, with considerable energy, as upon him depends the accuracy of the whole process of coining; he has not unfrequently so to manage his work that, upon 5,000,000 of sovereigns coined, he should arrive to within one sovereign of the calculated value.

The fillets, having been thrown by the tryer into the receptacles which indicate the particular cutting-out punches to which they are to be taken, are fetched by a man, who wipes off the oil, and then carries them to the cutting-out room, where the fillets are cut into blanks and scissel. The cutting-out presses used in the Royal Mint are very cumbersome, and when in operation are terribly noisy; it is therefore hoped that at no distant period they may be replaced by some of a far more simple construction;

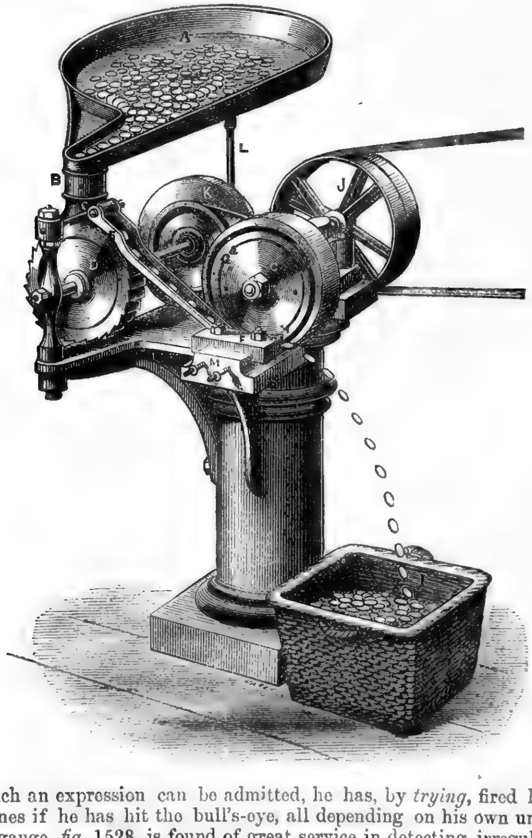
but it is believed that under all circumstances it will be found wise to adhere to the plan of cutting out a single blank at each descent of the punch. For bronze it is well to obtain five or more blanks at each blow, but the limited variation of weight allowed by law on blanks of the precious metals would render this false economy. *Fig.* 1536 represents one of the twelve cutting-out presses, which are all driven by a wheel provided with a series of cams on its outer rim; one of these cams is in the act of striking the friction-roller, F, which is attached to, and forms part of, the lever D. D is fixed to an upright shaft, which at E is cut with a screw-thread working into a female-screw fitted into the main-shoulder of the press at C. If now the cam strikes F, and throws it outwards, it causes the shaft D to take a part of a revolution, and in so doing the screw E makes it rise and carry with it the block N, whose tendency to circular motion is prevented by a plug fitting into its groove, and fixed in the guide O. The lower end of N carries a screwed cap, which supports the cutting-out punch, so that when E rises it carries the cutting-out punch through just the same distance that itself travels upwards. The cutting-out punch is now ready for action, and is released by the continued revolution of the wheel; but, as it could not fall with sufficient force of itself, assistance is rendered by the pressure of the atmosphere, as will be seen by the following arrangement. The lever D is provided at H with a loop of iron travelling on a screw, so that it may be moved farther from, or nearer to, the centre of action, and thus admit of the increase of power. This loop of iron is represented by H, and is continued by a rod of iron across the upper part of the room, and through a hole in the wall to a system of levers, from which a rod is suspended, the lower end being connected with a piston working in a chamber. The chamber is an hermetically-closed vessel secured to a stone firmly fixed in the floor. The piston works in this chamber, and is covered with about 2 inches of oil, which prevents the access of the atmosphere by leaks to any part beneath the piston. If the piston, therefore, be raised from the base of the chamber, a vacuum is produced in that portion from which the piston is removed, and consequently the atmosphere presses on the surface of the oil, which in its turn presses on the piston, and carries it down; in its fall the piston pulls down the cutter, which has been raised; for the same blow which raises the cutter also raises this piston; therefore, when the cutter is raised the workman places the fillet from which blanks are to be cut on the bolster, shown beneath O, and holds it firmly while the cutter descends and punches out a blank, which falls through the bolster into a drawer. By the time that the down-stroke of the cutting-out punch is complete, the wedge B has entered a slit in the spring R, and strikes the spring, thus throwing the machine back, and preparing it to start when the cam shall strike the friction-roller F. The point at which B may strike R is determined by a screw near the left hand P. The upright shaft D, which is partly hollow, terminates at a flat cogged wheel, and the upper part of E is made to pass into D; while at S is an arrangement which serves to detach or connect these pieces, that the cutter may upon occasion be used by the hand by means of the lever T, as well as to admit of the necessary alterations, as the punches, by regrinding, become shorter. The cutting-out punch, when it rises, carries with it the fillet from which the blank has been punched, until the fillet comes against the guard *b*, which detaches it.

1536



The fillets from which the blanks have been punched have the appearance of ribbons perforated with round holes, and are now called *scissel* (from the Latin *scindo*, to cut). These are taken at intervals, and bound up by strips of the same into bundles of 180 ounces—in the case of silver 360 ounces—ready for re-melting. The cutting-out press is set at liberty to start by the workman pressing his foot on a lever in connection with the line and spring; and so long as he keeps this lever down, the press is worked continuously, but when he releases it the spring catches the extreme end of D at G, and motion is arrested. The blanks which accumulate in the box are collected at frequent intervals and examined, to see that their edges are smooth; if they be ragged, as may happen from the wear or fracture of the edge of either the cutter or bolster, a loss of weight would be entailed subsequently which would cause the coin to be outside the prescribed limit, and to pass at an illegal weight into circulation, as the rough edges would be removed after the coining of the blanks had been effected. According to the quality of the work—the character of the gold—under operation, the tryer tests more or less frequently the variations of weight in a given number of blanks. This process is called *pounding*, and is, next to the *trying*, the most important of his duties; if such an expression can be admitted, he has, by *trying*, fired his shot, and here determines if he has hit the bull's-eye, all depending on his own unaided judgment. The gauge, *fig.* 1528, is found of great service in detecting irregularities as to diameter and thickness, which would not be, and are not, detected by weight, for the weight may remain equal, although both diameter and thickness may vary. All these points require considerable care on the part of those whose duty it is to attend to them; for the quality of a coinage is determined in this room: blanks which once leave it cannot be afterwards altered. The subsequent operations, being purely mechanical, would be quite as well performed by automaton machines.

1537



The completing processes form undoubtedly the prettiest and most interesting part of the operation of coining; nevertheless the processes already described constitute its most essential features. The blanks are weighed from this room in drafts of about

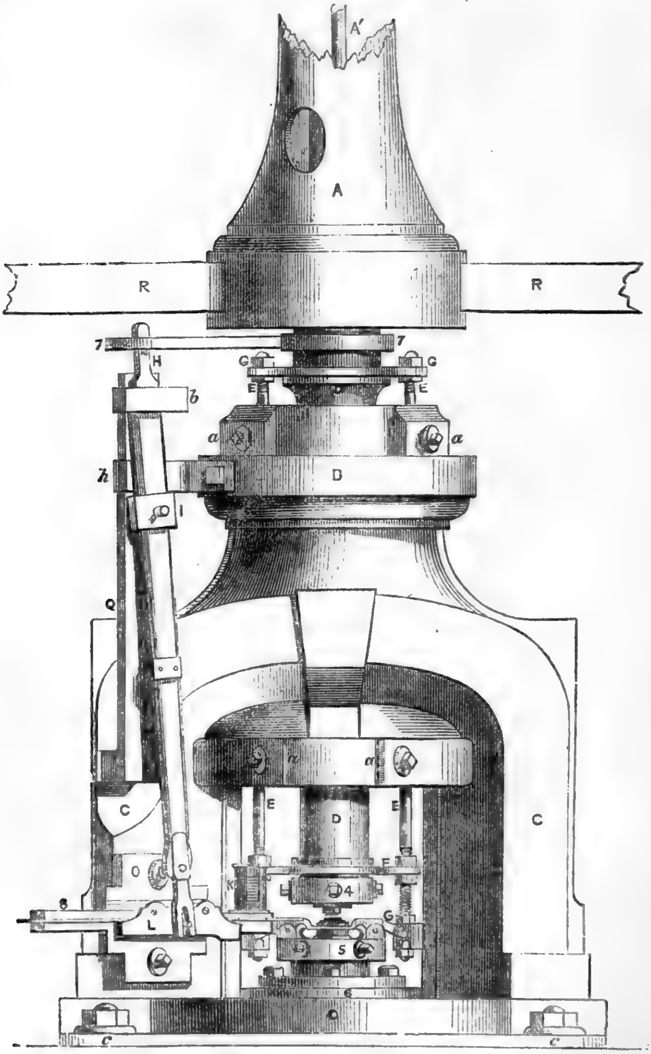
720 ounces, and placed in bags; each bag, therefore, contains four *journeys* of about 180 ounces each. These bags are placed on trucks and taken into the marking-room, where they are emptied, and the blanks submitted to the action of a machine whose operations reduce the diameter of each blank by compressing its edge. It is called Jones's Edge Compressor. *Fig.* 1537 represents Mr. Jones's machine. The blanks are placed in the hopper A, and fall by an incline into a tube B until they rest at C, on a notched wheel D. As D revolves each of its notches carries away the bottom blank of the pile from the tube B, and leaves it to slide down the tube E till it reaches the block F. The block F is cut with a narrow groove, which exactly corresponds with the groove G^a on the plate or disc G. The disc G revolves, and as the blank slides down and comes with some little impetus against the groove in the block F, the groove G^a catches it, and causes it to take two revolutions between the disc G and the block F, finally permitting its escape at H, when it falls into I, being now reduced in diameter and thicker on the edge, but its centre remaining as it was before. The machine is driven by J, the shaft of which carries a reduced rigger for the driving of K. The hopper is supported by the rod L. The distance between F and G represents the diameter of the blank after its edge is compressed, this distance being determined by the screws seen at M. Blanks of all diameters may be compressed at this machine if the block F and the plate or disc G be removed and replaced by others, neither operation taking many minutes. The edges of the blanks are compressed at the rate of 700 per minute. A boy of fourteen could work this perfectly well, and with more convenience now that the hopper is replaced by such an one as is used to supply Mr. Cotton's weighing machine. The edge of the blank is compressed with a view to prepare it for the *crenating* to be given by the collar in the after process of conversion into a coin.

The blanks are conveyed from the edge-compressor to the annealing-room, where they are freed from oil and placed in copper tubes, some charcoal being sprinkled on them to prevent the action of atmospheric oxygen on the alloy so far as possible. The tubes are then placed on iron carriages, and run into reverberatory furnaces, heated by Juckse's smoke-consuming apparatus, where they remain for an indefinite period. The furnaces are like that represented in the rolling-room for annealing the fillets in copper-tubes. To anneal the blanks, the temperature should be raised rapidly until the tubes attain a full red heat; and the time allowed for the operation should be from twenty to twenty-five minutes at the utmost. After the heating, the tubes are withdrawn from the furnace and placed on the floor of the room, till the blanks are assumed to have become cool. The charcoal is then sifted away, and the blanks cleaned and taken to the press-room to be coined. There are, nevertheless, some soiled blanks, which are blanched in dilute sulphuric acid.

The blanks taken from the annealing-room are each by a single blow of the coining press converted into coins possessing the obverse and reverse impressions, as well as the *crenated* edge, which is one of the means employed to protect the coin from the peculations of the clippers, those enemies to coin of all ages and all countries, but whose business has departed, not so much from the crenated edge as from the better balances placed in the hands of almost every man—certainly within reach of every man. The crenated edge is known to be no protection against the plan called 'sweating,' and which is effected by shaking the new coins in bags, when perhaps an ounce of gold may be obtained from 1,000 new sovereigns. The sovereigns thus treated are passed, and the operator makes his profit, but the light gold is detected by the balance, not by the eye. This is not the place to discuss such a question, so that we pass on to a description of the machine which is used to give the image and superscription to coins which will be current in accordance with the law.

The engraving illustrates Mr. Boulton's screw coining press, which alone we describe, although there are also lever presses in the Mint. The blank is laid by the automaton hand L, on the lower die; L, retires, and the collar then rises and encloses the blank, while the upper die, fixed to the main screw of the press by the securing apparatus 4, comes down with a blow estimated to be about forty tons, and, striking the blank, causes its particles to re-arrange themselves, and to assume the form given by the engraving on the dies and the crenated collar which surround them; in other words, the plain blank becomes by one blow a coin in every way complete. The following description will convey to the reader an explanation of the processes as they arise. The press having been set at rest, with the fullest space between the dies, is called *up*—that is to say, the upper die has been raised from the lower die, and in this position the automaton hand L has conveyed a blank from the tube K to, and holds it over, the lower die; upon the first motion of the press downwards, the eccentric wheel or cam 7 causes the lever H, which works on the pivot 1, to withdraw. The lever H may be lengthened or shortened at pleasure by an arrangement at the lower end. The first motion towards the withdrawal of L causes its finger or hand to open, and to release the blank, which falls upon the face of the lower die. The opening of the finger, or hand, is effected by a pin which works in a slit in the moveable finger of L. The continuation of the motion which draws back L, causes the rods E, which are carried by the main screw D, to release the collar by the levers G. The collar being thus relieved from downward pressure, rises by the elasticity of the springs until it wholly encloses the blank which has been left on the lower die. The rods E pass through the shoulder of the frame of the press, and are destined for

1538



another service besides that just described; for the main screw D, which travels through a female-screw fixed in the frame of the press, thereby receives its power to rise or fall upon each part of a revolution, whereas the upper die must strike the blank a blow just such as would be struck by a hammer, and without a twisting motion; therefore that motion of D is lost just below the lower D, where D fits into a cup suspended rigidly on, and is prevented from twisting by, the rods I, as shown at F.

To the lower part of the cup is fastened 4, which carries the upper die. So that, just at the moment that the levers G have permitted the collar to enclose the blank, the upper die reaches the full force of its blow, and comes upon the blank. The force of the blow, by converting the blank into a coin, causes an instantaneous recoil of the screw D, which is assisted in its rise by a kind of balance just equal to its weight. The nature of this arrangement will be better understood by reference to *fig.* 1538, where the funnel-shaped tube A is seen to be traversed by a rod A′, which terminates in the head of the screw D; the opening in the funnel being for the convenience of fixing this rod to D. At the top is a swivel, where the twisting motion is lost. It is connected at its upper end with a balanced beam, the other end of which is in communication with a partially-exhausted chamber: an arrangement which, while it becomes a counterpoise to the weight of the press, is used as a regulator of the blow to be given, so that it is quite possible to coin blanks of differing denominations by the agency of this chamber without altering the vacuum in the large vessel; for it must be explained that the motive power of the press, that which brings down the die with force, is gained by the pressure of the atmosphere.

As the coined money issues from the press it is collected in trays and examined; all imperfect coins, curiously termed 'brockages,' are picked out; and the good coins weighed into drafts of 701 sovereigns, equal in weight to about 180 ounces; these are at present sent to the weighing-room, where they are examined for imperfect coins, by passing over a kind of blanket, so arranged on a series of rollers that each coin lying on its surface can be seen as the blanket revolves.

1539

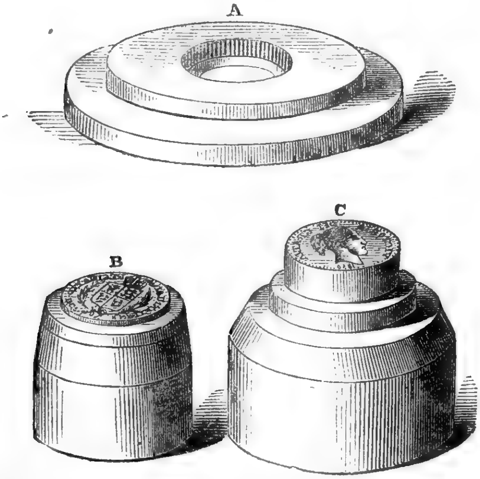


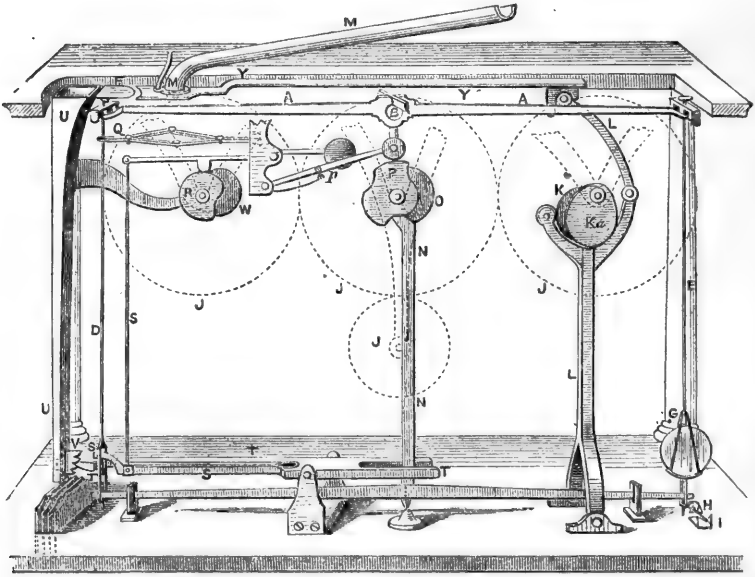
Fig. 1539 gives a view of the milled collar A. B being a representation of the lower die, with its long neck which fits nicely into the milled collar A. C, the upper die, also passes to a small distance into the collar, so that at the moment of the blow the blank is absolutely enclosed. The blow, which is estimated at 40 tons, forces the metal into every engraved part of the collar and dies. The press, which has been described with as few technical terms as possible, coins from 60 to 80 blanks per minute, finishing by one blow the obverse and reverse impressions, and adding the milled edge. (For the manufacture of dies, see DIES.)

The coins when struck are collected at frequent intervals and carefully overlooked to find any which may be defective, for with all the beauty of the mechanism of the press, accidents cannot be avoided, and it is found that about one coin in 200 is imperfect in its finish whatever its size or value. The imperfect coins are returned, with the ends cut from the bars, the scissel, and the imperfect and out-of-remedy blanks, to the melting-house every morning. The coins are weighed into bags, each containing 701 sovereigns, and at intervals, depending on the requirements of the Bank, sent to the weighing-room, where each coin is weighed separately in Mr. Cotton's balance.

Mr. Cotton's weighing-machines form perhaps the most elegant and clever invention of modern times. They effect the process of weighing far more accurately than man can hope to do; and with extraordinary accuracy determine the weight of about 23 coins per minute. Peculiarly admirable as are these machines, their perfection has been greatly increased by improvements suggested by Mr. Richard Pilcher, who has immediate charge of those in the Royal Mint. Mr. Pilcher, whose inventive genius is only equalled by his desire to give to the public the benefit of his inventions, has rendered these automaton balances serviceable to the Mint; whereas, when they left the hand of Mr. William Cotton, they were of great service to the Bank of England alone, for there only two determinations, or in fact one determination is necessary. In that institution it is required to show that the coins issued by it are not below the legal weight for circulation, whereas the Mint must guarantee that coins leave its works neither above nor below the limits fixed by law; hence the necessity for the incorporation of Mr. Pilcher's improvements with Mr. Cotton's beautiful invention.

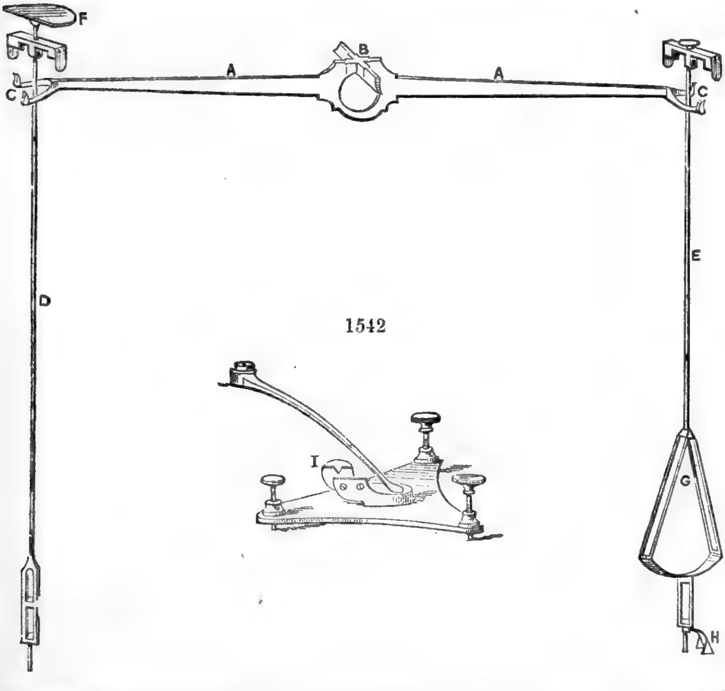
Fig. 1540 exhibits a view of a model of Cotton's automaton machine, for the purpose of illustration; and it should be mentioned that Messrs. D. Napier and Sons are the makers of the machines actually in use.

1540



The whole theory of this balance rests on the fact that the centre of gravity and the centre of action are in one line: either being disturbed, the balance is no longer equal. The machine gains its motion from a shaft fixed to the ceiling of the room. Steam contained in a boiler exists under an ever-varying pressure, arising from the amount of work which it may be necessary for the engine to perform, or from the irregular combustion of the fuel as well as from other causes. Since it is of the utmost importance that the automaton balance should be made to maintain a uniform pace, Messrs. Napier and Sons found it necessary to drive the shaft which gives it motion by a small atmospheric engine, which is placed in the weighing-room. It has been found that a chamber may be kept equably exhausted of air, if the atmosphere be admitted to it by a uniformly-weighted valve. Such a chamber is used in the Mint for other purposes, and Messrs. Napier conducted from this a pipe, by the agency of which the atmospheric engine is worked with a far more even and steady motion than could be obtained by steam; in fact, the exhausted chamber becomes a regulated spring, which softens down the variations in the motion of the steam-engine. The shaft supported by the ceiling conveys its motion to the weighing-machine by a line which, passing over friction-wheels, circulates round a stepped-wheel, which runs loose on the shaft communicating with J. The line is maintained with sufficient rigidity by a weight which is suspended at the end of the lever carrying friction-wheels. The weight is just sufficient to insure the continuous working of the machine, but it is so light as to permit the line to slip in the event of anything going wrong in the works of the balance. When the machine is to be set in motion, a kind of cheek is made—by screwing—to touch the face of the stepped-wheel, and thus, by friction, gives motion to the wheel J. This is an elegant mode of meeting a chance of accident, for in the event of the weight proving to be too heavy, any extra force simply disconnects this cheek from the face, and so stops the machine. The machine having been set in motion, the small wheel J (by communication with the larger wheels, J, all of which are driven by it), causes the cam K *a* to push forward the lever L, which pushes forward the flattened continuation of Y indicated by dotted lines, until it moves a coin placed in the collar at the bottom of the hopper M, on to the scale-pan F, which, for the sake of clearness, is isolated, and will be seen in *fig.* 1541. So soon as the coin has been placed on the scale-pan F, the cam P lowers a lever, *p*, the office of which is to permit the opening of the forceps Q, and thus to release the rod D, dependent from F upon the knife-edge C. The forceps are closed by the cam P, which raises *p*, and by it compresses an attached spring. The forceps are intended to hold *this* rod, D, while the coin is placed on F, because the friction caused by the placing of the coin would have a tendency to push F from the knife-edge on which it is suspended, and thus blunt its delicate edge. While the forceps are opened the cam O, by its partial revolution, lifts the rod N, which is steadied in its motion by a pin rising from it and entering the inverted arch; its lower extremity working into a socket on the table on which the whole frame of the machine stands.

1541



1542

Towards its lower extremity the rod N will be seen to branch out right and left, until each end passes through a kind of step in the rods D, E, indicated more distinctly in *fig.* 1541. The office of this rod is to bring the beam, from which the rods D, E, are dependent, to a dead level, as well as to release both ends of the beam by one action. At the moment that the forceps Q have released the rod D, the cam O, by N, releases both the rods D, E, by rising from the steps, thus permitting the beam to determine the weight of the blank placed on F. A close inspection of the illustration will show that the rods A are suspended from and rest upon the knife-edges, C, of the beam, A, which has a centre knife-edge, T, by which the whole mass is supported and poised. The knife-edges are made to find their own planes or resting-places upon curved or hollow pieces of steel, thus securing the smallest point of contact with a certainty of the smallest amount of friction. In ordinary balances the substance to be weighed is placed in a pan, which is on the same level as the pan which contains the counterpoise; but in Mr. Cotton's balance this condition is of no consequence, so that the counterpoise rests ultimately upon a point which is at the same distance from the centre of action as the point upon which the matter to be weighed rests. The counterpoise, G, is placed in a kind of cage, and any variation from this standard is at once indicated, even if it reach only to the thousandth part of a grain. By law, the weight of a coin may vary to a certain extent from a standard weight; the variation or latitude allowed is called *remedy*, from the Latin *ad remediam*; and in weighing, this remedy is taken advantage of by a contrivance much simplified by Mr. Pilcher. The weight of a sovereign is 123·274 grains, but it may by law be either 123·474 grains, or it may fall to 123·074 grains. Mr. Pilcher therefore reduced the counterpoise to the minimum allowed, thus avoiding the placing of a remedy-wire for the light side; and he then made the remedy-wire *q* (shown in the first enlarged portion on the left-hand side of the illustration), which is placed on the stand I, upon a peculiarly-formed point indicated in *fig.* 1542, so heavy that any blank which would not raise it and the counterpoise, must be within the remedy on the *heavy* side. In accordance with this arrangement, the continuation of the rod E is terminated by a cage, so that if a coin be so *light* as to be unable to raise the counterpoise until the stirrup comes in contact with the remedy, it is too light to make a legal coin. This fact being determined, the motion of the machine causes the cam K to bring back the rod L, that it may be ready when required to push forward another coin, and the forceps Q to grasp the rod D, while the cam R permits the falling of the rod S, which is nearly counterpoised by the ball *m* (the precise length of the rod being regulated by the screw *j*), until its finger rests upon the indicator. The depth to which S shall fall is fixed by the step (shown in the enlarged portion of *fig.* 1541). This is, of course, determined by the forceps, securing D at the position indicated by the weight of the blank. The indicating-finger having come to rest, the continued motion of the machine causes the cam, W, to permit the shoot, U, to fall until one of its steps, V, comes into contact with the indicating-finger, when the lower part of the shoot must be exactly over, and form part of, one of the tubes which terminate in boxes labelled respectively 'heavy,' 'light,' 'medium.' The shoot having taken its position, the continued motion of the machine causes the cam K to induce the placing of another coin on the scale-pan F, and this coin, by advancing, pushes off the one just weighed, which, falling into and through the shoot, passes to the compartment reserved for it. Suppose the newly-placed coin to be too heavy for forming a legal coin, the same operation goes on, but it now lifts not only the counterpoise, but also causes the stirrup at H to lift the remedy-weight. This is a most delicate operation, for if a blow, however slight, be given, it would cause unsteadiness in the beam. Mr. Pilcher therefore determined to make the carriage, W, *fig.* 1542, which supports the remedy-wire, stand upon micrometer screws, by which the remedy-wire is made just to touch the stirrup, without pressure, while it also rests upon the most minute points, formed by cutting away every part of I which is not actually required—in fact, shelving it out. The scale-pan F is protected from draught by a lantern, while the coins are directed into the collar by a guard, as they slide down the hopper.

Some new machines have recently been supplied to the Mint by Mr. James Napier, but it is not certain that these are cheaper than the old ones. That they are lower in price may be admitted, and they are certainly more convenient in use, from the fact that the wheels shown at F are placed at the back. It is, however, to be regretted that Mr. Napier did not introduce into these new machines the recent inventions of Mr. William Bradshaw, which are supremely simple; and, now that they are effected, one cannot but wonder that so many minds having been engaged on these machines, improvements such as these have not earlier seen the light. To Mr. Bradshaw, particularly, great credit is due, for he was obliged to overcome, not only innate difficulties, but difficulties of position, and these latter were of no mean kind. It is to the credit of the Mint authorities that they finally adopted these improvements, and ordered the necessary alterations to be made in *all* the machines.

Mr. Bradshaw's improvements enable the automaton balances to weigh 30 per cent. more coins in the same time; yet they permit each coin to occupy a longer space of time in being weighed. This would appear to be a mechanical contradiction; but if reference be made to *fig.* 1540, it will be seen that the cam K pushes forward the lever L, which ultimately, by the slide, pushes the blanks on to the scale-pan F. By altering the shape of the cam K, Mr. Bradshaw causes it to do its work more rapidly, and thus leaves the piece on F longer than before; but that this time may not be lost, he alters also the shapes of the cam P, and of the cam O, so that the forceps Q are opened, and the beam is released more rapidly: thus the balance would be longer in action; but to utilise the time ready to be saved, he alters also the driving-pulley J, causing the machine to make 30 per cent. more determinations per minute, and that this may be effected with greater certainty he reduced the depth of the step, shown at V, to just one-half, so that the beam has to travel only half the distance it formerly travelled to determine the position of the light, heavy, or medium piece. He next proceeded to alter the rod N, because he observed that it received a tilting motion, arising from its being lifted by a shoulder, as shown in the woodcut. To overcome this defect he made the rod straight up to a certain point, where he divided it into a kind of loop which passed over the cam O, which, as it revolves, lifts this rod perpendicularly. He still found that the cam, O, had a tendency to push this rod against its bearings, so he placed a spring of brass between the top of its loop and the cam O, and by this contrivance made the cam to lift the brass, and that in its turn to raise the rod N. There was yet another difficulty, caused by an occasional stoppage of the action of the spring which softens the descent of the bearing of the rod, N, into its lower socket; this he removed by cutting a hole in the side of the socket, so that it can be seen at once if the spring be in action.

Great inconvenience arose from the collection of dust, spangles of bullion, and other foreign matter on parts of the balance. This Mr. Bradshaw overcame by two simple contrivances: first, he pierced the bottom of the grooved trays, so that these substances might in a great measure fall through while the blanks were being arranged in rouleaux, thus separating the largest pieces, which, falling down the shoot, would stop its action; and, secondly, he placed a glass shelf midway between the table and the beam, that is, beneath the hopper M, where it terminates, and above the beam A, where it is seen near the forceps Q, thus protecting the beam and forceps. These may appear to be trifling alterations: they are, nevertheless, to Cotton's balance what the compound metal balance-wheel is to a watch. Mr. Pilcher was granted an honorarium of 40*l.* for his invention of the file (to be described), but it is hoped that he and Mr. Bradshaw will be rewarded more generously for their improvements in Cotton's balance; for if, by judicious liberality, encouragements are offered to those in the Civil Service to give to the country the benefit of their inventions, we may hope that Government institutions will bear comparison with ordinary commercial manufactories as regards the developement of inventive genius. Nor is this a small matter, for all the working improvements in the Cotton balance have been made by those whose duty it is to attend to their working; yet no acknowledgment, either direct or indirect, has been made to the officers concerned. It is said that their salaries cover all their time and energy. This may be true, but such a policy is not calculated to result in great steps towards perfecting either machines or processes.

It is well to state that the beam in Mr. Cotton's balance is 8·90 inches in length, and that its weight is 288·41 troy grains.

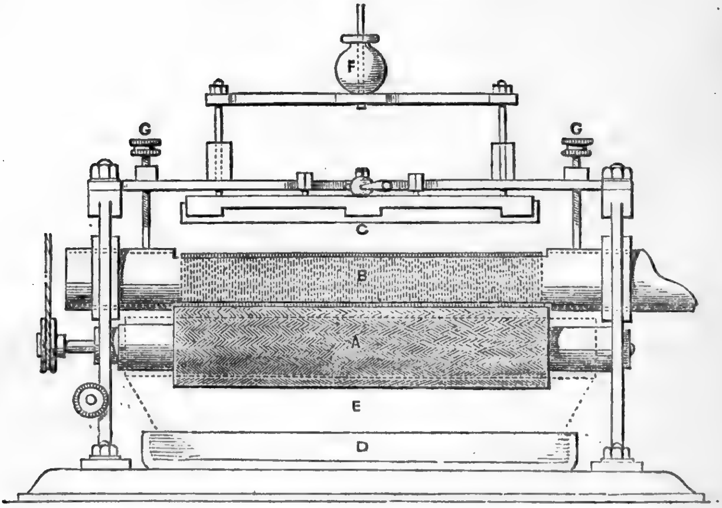
After overlooking, the coins are rung as blanks used to be, and then weighed separately, *all* the rejected going to the melting-pot, by which a waste of 50 per cent. is incurred at the extreme end of an elaborate process; but this unwise course, it is to be hoped, will soon be abandoned when its expensive and perfectly useless extravagance is considered. After the various operations of the weighing-room, the coin is collected and weighed into separate bags, each containing 701 sovereigns; the exact weight of the contents of each bag is noted; and the bags, having been placed in a truck, are taken to the Mint Office, where they undergo what is called *pyxing*, which is simply the selecting from each and every bag a pound weight, from which two coins are taken; each coin is weighed, and its weight recorded. Of these coins one is placed in the hands of the assayer, to determine its value as to per-centage of gold, and the other is sealed in a packet, which is placed in a *pyx* for the trial of THE PYX at Westminster—an ancient process now useless, because any skilled man can detect by assay a deterioration of the coin. These particulars having been taken, the coin is in due course delivered to the officers of the Bank of England, who conduct it in amounts of about 140,000*l.* to the Bank in a waggon.

It is to be regretted that the system so long adopted, and founded on the experience of years, has been altered, to the manifest disadvantage of the public; for it will be observed that under the circumstances which now obtain, there must be an enormous waste at the extreme end of a tedious and expensive process. For all coins which exceed the limits of the remedy, on either the light or the heavy side, are obliged to be remelted, because there is no practicable means by which the light pieces can be increased in weight, or the heavy pieces reduced, so as to bring them within the remedy. Thus, therefore, as much as 50 per cent. of finished coin is uselessly sacrificed. If this loss became one of money value alone it would be hard to bear, but it has, in addition, the effect of reducing the out-turn of the Mint, and has thus caused considerable dissatisfaction amongst the commercial world by producing a great scarcity of coin, for it has happened that so much as 70 per cent. of all the work done has required to be remelted. Now it can be understood if, say 50 per cent. of the work produced be lost, it amounts to a practical reduction of the powers of the Mint, and this reduction, wilfully incurred, has been used as an argument for the necessity of building new mint premises; instead of so expensive a plan being continued, the Mint authorities should return to the proper system of coining, by which the blanks were weighed before coining, and thus such pieces as were too heavy could be reduced by the file.

This file was invented by Mr. Pilcher, who, being the officer of this room, considers his duty to be neglected if there be any improvement capable of being made, but which is left undone: he never tires till the invention is complete, and the machine made. Mr. Albert Barre, the distinguished engraver to the Paris Mint, declares this file to have surmounted all the difficulties he has met with in this part of the process. In his own words, 'It leaves the face of the blank untouched, and free to develope the work of the engraver, which no other file does or can effect, because any metal which is *ploughed* out from the face of a blank leaves a hole which is not filled up in coining.'

Feeling that this much-desired re-introduction will take place, it is thought wise to give the following description of Pilcher's file, which, if not desired for the benefit of our own Mint, will be adopted by other coining countries:—*Fig.* 1543 is a representation of this compact machine. The blanks are placed in rouleaux in a tube, B, which is open at top and at bottom; through the opening at the bottom the blanks rest their *edges* on the file, A, which, as it revolves about 1,000 times per minute, files off metal from the edge of the blank. Each machine has two tubes, and when both have been filled the rod, C, which carries a triangular knife-edge, is released by a lever, and the knife-edge resting upon the upper edge of the blanks, B, with the intention of offering resistance to their rotary motion, enables the operator to remove *much or little* metal from their edges at pleasure by increasing the resistance which C offers by adding a weight, F, on to the gallery. D is a glass dish into which the dust, as it is removed from the edges of the blanks, falls, thus insuring a perfect *separation of the dust* from the blanks. The blanks in B are kept in their position by small blocks of ebony, which are secured by the thumb-screws, G. Motion is given by the wheel, J, which communicates with the driving pulley by a cord or catgut. The whole machine stands on a block of mahogany secured to a table of oak. A hopper of brass shown by dotted lines is provided, with a view to catch flying particles of the precious metals. Each file reduces 250 sovereign blanks per minute.

1543



The coined moneys are rung by boys to detect any which may be dumb or cracked, and which are rejected for melting. Dumb or cracked pieces arise when bubbles of air are enclosed in the bars at the time of pouring the fluid metal into the moulds in the melting-house.

Besides this source of dumb work, may be mentioned another of large occurrence in silver, and occasionally met with in gold, which results from an imperfect mixture of the alloy at the time of melting, and developes itself at the draw-bench, where whole fillets, of six feet long, may be seen to separate into two complete layers of metal, the inner surfaces being coated with a thin film of copper, frequently quite pure, but sometimes in the form of suboxide. It would thus appear that a globule of copper becomes enveloped in a volume of fluid gold or silver, and, in the act of pouring, this globule is drawn out into a kind of wire, perhaps extending some inches in length, enclosed in precious metal. When this is rolled it is all flattened together, but there is no adhesion between the surfaces, so that when the fillet passes through the draw-bench, the lateral motion given to the atoms of the metal causes the slip which finally separates the two surfaces of metal, and the eye at once detects the existence of the fault.

The law enacts that 20 lbs. weight troy of standard or crown gold shall be made into 934·50 sovereigns, and this proportion gives the means of determining the theoretical weight of one sovereign; for if the 20 lbs. troy weight produce 934·50 coins, it is only necessary to divide by that number the number of grains in 20 lbs. troy, and the quotient will represent the weight of a single sovereign, viz., 123·2744783306581059 troy grains; therefore the journey of 701 sovereigns should weigh 180·032102728731942215 troy ounces, and a million 256821·829855377 troy ounces, equal to 7·8618927506797 tons avoirdupois; hence the War Indemnity of France weighed 1572·37855 tons.

The following measurements, taken from a set of proof coins of the present reign, will convey an idea of the probable size of any coin of the realm; but from the reason before stated, a man need not be disappointed should he find the diameters differ from any he may examine by an accurate gauge. While stating the diameters (which never vary beyond a few thousandths of an inch), it is thought proper to give the legal weight and legal tender of each denomination of coin current in Great Britain:—

Denomination of Coin		Diameter	Weight in Troy		Legal Tender
		inches	grains	ounces	To the value of—
Gold	Sovereign	0·8680	123·2744	0·2568	The highest sum known.
	Half-sovereign	0·7622	61·6372	0·1284	
Silver	Crown	1·5048	436·3636	0·9090	Forty shillings sterling.
	Half-crown	1·2714	218·1818	0·4545	
	Florin	1·1826	174·5454	0·3636	
	Shilling	0·9296	87·2727	0·1818	
	Sixpence	0·7648	43·6363	0·0909	
	Fourpence	0·6456	29·0909	0·0606	
	Threepence	0·6383	21·8181	0·4545	
	Maundy				
	Fourpence	0·6957	29·0909	0·0605	
	Threepence	0·6383	21·8181	0·4545	
	Twopence	0·5294	14·5454	0·0303	
	Penny	0·4388	7·2727	0·0151	
Copper	Penny	1·3502	291·6666	0·6076	One shilling sterlg. [1]
	Halfpenny	1·1155	145·8333	0·3038	Sixpence ,,
	Farthing	0·8575	72·9166	0·1519	Sixpence ,,
	Half-farthing	0·6953	36·4583	0·0759	Sixpence ,,
Bronze	Penny	1·2000	145·8333	0·3038	One shilling ,,
	Halfpenny	1·0000	87·5000	0·1822	One shilling ,,
	Farthing	0·8000	43·7500	0·0911	One shilling ,,

It appears that the Royal Mint should sustain less loss than any other mint by the coining of gold and silver. If allowance be made for the sale of the sweep or dust which results from a coinage, the total loss, inclusive of every operation in coining, should be so small that it might be passed without notice; in fact, there ought to be a minute increase of weight from traces of oil which are left on the fillets to enable them to pass through the cylinders of the draw-bench. By melting there seems to be some loss of metal: this should reach about 100*l.* per million coined; such loss would be wholly explained by refining, through the removal of copper by oxidation; although this is minute, still it is enough to explain the loss which is thus indicated.

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[1] Proclaimed illegal since 31st December 1869.

If the assays be closely watched there can be no loss, for the trial of the pyx invariably shows the gold coin to err on the side of purity. Therefore, if the Master of the Mint should determine to issue gold of exact standard, he may fairly cover every source of loss, and coin money without waste of metal. Each grain that is found in excess of the standard upon the pound weight of gold causes a loss of about 180*l*. upon each million coined. The moneyers formerly sustained a loss of about 700*l*. for each million coined, such loss being exclusive of melting. This has never been entirely satisfactory; and the loss by coining alone rarely reached so high an amount, although 373*l*. per million would seem to have been determined by some careful experiments as the necessary loss. This gold, it will be easily conceived, was lost by volatilisation, and by other small sources of water in so extensive an operation as that of coining. Although it is perhaps impossible to avoid all loss, it appears to be reduced to a minimum by the great attention that is now paid to every division of the process.—G. F. A.

MIRABILIS. A genus of plants belonging to the natural order *Nyctaginaceæ*. They are known to the French as *Belles de nuit*. The Peruvian species *Mirabilis jalapa*, or false jalap, has a purgative root, which was formerly mistaken for the true jalap. *M. dichotoma* is the well-known garden flower commonly called the 'Marvel of Peru,' or the *Fleur de quatres heures* of the French.

MIRBANE, ESSENCE OF. A fancy name under which M. C. Collas, of Paris, sold nitrobenzol.

MIRRORS. Under GLASS MANUFACTURE, the process of casting the large plates for mirrors has been described. We have therefore only to describe in this place the preparation of the plate glass and its silvering.

The smoothing of the plates is effected by the use of moist emery washed to successive degrees of fineness, for the various stages of the operation; and the polishing process is performed by rubbers of hat-felt and a thin paste of colcothar and water. The colcothar, called also crocus, is red oxide of iron prepared by the ignition of copperas, with grinding and elutriation of the residuum. See COLCOTHAR.

The last part, the polishing process, is performed by hand. This is managed by females, who slide one plate over another, while a little moistened putty of tin finely levigated is thrown between.

Large mirror-plates are now the indispensable ornaments of every large and sumptuous apartment; they diffuse lustre and gaiety around them, by reflecting the rays of light in a thousand lines, and by multiplying indefinitely the images of objects placed between opposite parallel planes.

The *silvering* of *plane* mirrors consists in applying a layer of tin-foil alloyed with mercury to their posterior surface. The workshop for executing this operation is provided with a great many smooth tables of fine freestone or marble, truly levelled, having round their contour a rising ledge, within which there is a gutter or groove which terminates by a slight slope in a spout at one of the corners. These tables rest upon an axis of wood or iron, which runs along the middle of their length; so that they may be inclined easily into an angle with the horizon of 12 or 13 degrees, by means of a hand-screw fixed below. They are also furnished with brushes, with glass rules, with rolls of woollen stuff, several pieces of flannel, and a great many weights of stone or cast-iron.

The glass-tinner, standing towards one angle of his table, sweeps and wipes its surface with the greatest care, along the whole surface to be occupied by the mirror-plate; then taking a sheet of tin-foil adapted to his purpose, he spreads it on the table, and applies it closely with a brush, which removes any folds or wrinkles. The table being horizontal, he pours over the tin a small quantity of quicksilver, and spreads it with a roll of woollen stuff; so that the tin-foil is penetrated and apparently dissolved by the mercury. Placing now two rules, to the right and to the left, on the borders of the sheet, he pours on the middle a quantity of mercury sufficient to form everywhere a layer about the thickness of a crown piece; then removing with a linen rag the oxide or other impurities, he applies to it the edge of a sheet of paper, and advances it about half an inch. Meanwhile another workman is occupied in drying very nicely the surface of the glass that is to be silvered, and then hands it to the master workman, who, laying it flat, places its anterior edge first on the table, and then on the slip of paper; now pushing the glass forwards, he takes care to slide it along so that neither air, nor any coat of oxide on the mercury can remain beneath the plate. When this has reached its position, he fixes it there by a weight applied on its side, and gives the table a gentle slope, to run off all the loose quicksilver by the gutter and spout. At the end of five minutes he covers the mirror with a piece of flannel, and loads it with a great many weights, which are left upon it for 24 hours, under a gradually-increased inclination of the table. By this time the plate is ready to be taken off the marble table, and laid on a wooden one sloped like a reading-desk, with its under edge resting on the ground, while the upper is raised successively to different elevations by means of a cord passing over a pulley in the ceiling of the room. Thus the mirror has its slope graduated from day to day, till it finally arrives at a vertical position. About a month is required for draining out the superfluous mercury from large mirrors; and from 18 to 20 days from those of moderate size. The sheets of tin-foil being always somewhat larger than the glass-plate, their edges must be pared smooth off, before the plate is lifted off the marble table.

Process for Silvering Concave Mirrors.—Having prepared some very fine Paris plaster by passing it through a silk sieve, and some a little coarser passed through hair-cloth, the first is to be made into a creamy liquor with water, and after smearing the concave surface of the glass with a film of olive-oil, the fine plaster is to be poured into it, and spread by turning about, till a layer of plaster be formed about $\frac{1}{10}$th of an inch thick. The second or coarse plaster, being now made into a thin paste, poured over the first, and moved about, readily incorporates with it, in its imperfectly-hardened state. Thus an exact mould is obtained of the concave surface of the glass, which lies about $\frac{3}{4}$ of an inch thick upon it, but is not allowed to rise above its outer edge.

The mould, being perfectly dried, must be marked with a point of coincidence on the glass, in order to permit of its being exactly replaced in the same position, after it has been lifted out. The mould is now removed, and a round sheet of tin-foil is applied to it, so large that an inch of its edge may project beyond the plaster all round; this border being necessary for fixing the tin to the contour of the mould by pellets of white wax, softened a little with some Venice turpentine. Before fixing the tin-foil, however, it must be properly spread over the mould, so as to remove every wrinkle; which the pliancy of the foil easily admits of, by uniform and well-directed pressure with the fingers.

The glass being placed in the hollow bed of a tight sack filled with fine sand, set in a well-jointed box capable of retaining quicksilver, its concave surface must be dusted with sifted wood-ashes, or Spanish-white contained in a small cotton bag, and then well wiped with clean linen rags to free it from all adhering impurity, and particularly the moisture of the breath. The concavity must be now filled with quicksilver to the very lip, and the mould being dipped a little way into it is withdrawn, and the adhering mercury is spread over the tin with a soft flannel roll, so as to amalgamate and brighten its whole surface, taking every precaution against breathing on it. Whenever this brightening seems complete, the mould is to be immersed, not vertically, but one edge first, and thus obliquely downwards till the centres coincide; the mercury, meanwhile, being slowly displaced, and the mark on the mould being brought finally into coincidence with the mark on the glass. The mould is now left to operate by its own weight in expelling the superfluous mercury, which runs out upon the sand-bag, and thence into a groove in the bottom of the box, whence it overflows by a spout into a leather bag of reception. After half an hour's repose the whole is cautiously inverted, to drain off the quicksilver more completely. For this purpose a box like the first is provided, with a central support rising an inch above its edges; the upper surface of the support being nearly equal in diameter to that of the mould. Two workmen are required to execute the following operation. Each steadies the mould with the one hand, and raises the box with the other, taking care not to let the mould be deranged, which they rest on the (convex) support of the second box. Before inverting the first apparatus, however, the reception-bag must be removed, for fear of spilling the mercury. The redundant quicksilver now drains off; and, if the weight of the sand-bag is not thought sufficient, supplementary weights are added at pleasure. The whole is left in this position for two or three days. Before separating the mirror from its mould the border of tin-foil, fixed to it with wax, must be pared off with a knife. Then the weight and sand-bag being removed, the glass is lifted up with its interior coating of tin-amalgam.

For Silvering a Convex Surface.—A concave plaster mould is made on the convex glass, and their points of coincidence are defined by marks. The mould is to be lined with tin-foil, with the precautions above described; and, the tin surface being first brightened with a little mercury, the mould is then filled with the liquid metal. The glass is to be well cleaned, and immersed in the quicksilver-bath, which will expel the greater part of the metal. A sand-bag is now to be laid on the glass, and the whole is to be inverted, as in the former case, on a support; when weights are to be applied to the mould, and the mercury is left to drain off for several days.

If the glass be of large dimensions, 30 or 40 inches for example, another method is adopted. A circular frame, or hollow ring of wood or iron, is prepared, of twice the diameter of the mirror, supported on three feet. A circular piece of new linen cloth of close texture is cut out, of equal diameter to the ring, which is hemmed stoutly at the border, and furnished round the edge with a row of small holes, for lacing the cloth to the ring, so as to leave no folds in it, but without bracing it so tightly as to deprive it of the elasticity necessary for making it into a mould. This apparatus, being set horizontally, a leaf of tin-foil is spread over it, of sufficient size to cover the surface of the glass; the tin is brightened with mercury, and then as much of the liquid metal is poured on as a plane mirror requires. The convex glass, well cleaned, is now set down on the cloth, and its own weight, joined to some additional weights, gradually presses down the cloth, and causes it to assume the form of the glass, which thus comes into close contact with the tin submersed under the quicksilver. The redundant quicksilver is afterwards drained off by inversion, as in common cases.

The following recipe has been given for silvering the inside of glass globes:—Melt in an iron ladle or a crucible equal parts of tin and lead, adding to the fused alloy one part of bruised bismuth. Stir the mixture well, and pour into it as it cools two parts of dry mercury; agitating anew, and skimming off the drossy film from the surface of the amalgam. The inside of the glass globe being freed from all adhering dust and humidity, is to be gently heated, while a little of the semi-fluid amalgam is introduced. The liquidity being increased by the slight degree of heat, the metallic coating is applied to all the points of the glass, by turning round the globe in every direction, but so slowly as to favour the adhesion of the alloy. The silvering is not so substantial as that of plane mirrors; but the form of the vessel, whether a globe, an ovoid, or a cylinder, conceals or palliates the defects by counter-reflection from the opposite surfaces.

Several processes have been introduced, and some of them patented, for precipitating silver on glass. These have not all been entirely successful, but the phenomena involved are of such an interesting character, that this article would be incomplete without some notice of them.

Mr. Drayton patented a process of the following character:—A solution of nitrate of silver, rendered neutral by the addition of a little ammonia, was floated over a plate of glass; or a vessel intended to be silvered was filled with this fluid; some spirits of wine was mixed with it, and then a small quantity of the oils of cloves and cassia added. By a complicated action, partly physical and partly chemical, metallic silver was separated from the salt in solution, and precipitated over the entire surface of the glass. The metallic film being of sufficient thickness, the solution was poured off, the coating well washed, dried, and protected from abrasion by a thick varnish or paint laid on the back. The defect in mirrors thus prepared was that small specks appeared in the silver, which became little centres of chemical action; the silver tarnishing, and circular spots extending from these points; so that the mirror, either for use or ornament, was ruined. The cause of this may be traced to the compound character of the solutions employed. Nitrate of silver, ammonia, spirits of wine, and essential oils, with water, form a very mechanical mixture, and as the silver fell, it no doubt entangled some of the organic matter, and this, however small, became the starting-point of those stains which eventually destroyed the mirror. Dr. Stenhouse showed that a large number of bodies possess the singular power of precipitating silver from its solution; amongst others, the following: gum-arabic, starch, salicine, gum-guaiacum, saccharic acid, aldehyde, oils of pimento, turpentine, or laurel, and especially grape-sugar.

Mr. Hale Thomson patented a silvering process which involved the use of grape-sugar. A certain portion of grape-sugar is put into a solution of nitrate of silver, rendered as neutral as possible, and a little heat is applied. By this means a beautiful film of very pure silver is spread over the glass. By a process analogous to this Foucault proposed to silver reflectors for lighthouses, and for telescopes. A process has also been patented involving the use of tartaric acid as the precipitating agent.

A method of coating glass with *platinum*, instead of silver, has been introduced in France, and carried out to some extent by Cresswell and Tavernier. A solution of bichloride of platinum is spread with a fine brush over the surface of the glass, and the metal is precipitated by means of oil of lavender.

MISPICKEL is arsenical pyrites. See Arsenic; Pyrites.

MITTLER'S GREEN. This colour has been made in France in limited quantities, for many years past, under the name of emerald green (*vert d'émeraude*), by MM. Pannetier and Binet, who kept their process secret. The great beauty of the product induced many to attempt its imitation. But its nature remained undiscovered; partly, no doubt, because the colour was observed to darken, and to emit steam when heated; circumstances which gave rise to an impression that it contained organic matter. When, at length, M. Guignet discovered the nature of the article, and the method of its production, he immediately patented his discovery, and, thus protected, was emboldened to enter upon its manufacture on a great scale, producing tons where the secret system had produced only pounds.

The preparation of Mittler's green is conducted in the following manner:—

A mixture of bichromate of potash and boracic acid, in the proportion of eight equivalents of crystallised boracic acid to one equivalent of the bichromate, or three parts crystallised boracic acid to one part of the bichromate, is calcined at a red heat. Oxygen and water are evolved, and a mass is obtained, which may be regarded as a double salt consisting of potassio-chromic borate. This is treated with water, which dissolves out boracic acid and borate of potash, leaving an insoluble chromic hydrate, which, when dried at a gentle heat and finely pulverised, constitutes the product in question.

The boracic acid is, of course, recovered from the wash of waters by the ordinary means for use in succeeding operations.

The mode of printing with this powder is similar to that adopted in printing with the ultramarines, albumen being generally employed as the fixing agent. Its use was at the outset attended with considerable practical difficulty, which, however, M. Kestner is stated to have now in a great measure overcome. The precise chemical constitution of this pigment is not yet fully elucidated, especially as to the question whether or not it retains any portion of boracic acid. On this subject, M. Guignet, after having described the process of its manufacture, observes that his product, like the hydrated binoxides of chromium, is converted by heat, first into the black binoxide, and subsequently (at a red heat) into the anhydrous sesquioxide. The loss of water during this transformation appears, from the mean of three analyses, to be 18·5 per cent.; corresponding to the formula, $Cr^2O^3. 2HO$ ($\mathbf{Cr^2O^3. 2H^2O}$), for the hydrate. This would show a proportion of water less than that of the ordinary hydrate, of which it nevertheless presents the general character. On the other hand, M. Guignet conceives that it may possibly retain traces of boracic acid, the presence of which, however, he has found difficult to prove. Boracic acid, acting at a red heat upon bichromate of potash, may, he remarks, produce simultaneously chromic and potassic borate, or even a double compound of the two. Theoretically, this would yield to water soluble potassic borate, leaving behind only the insoluble hydrated oxide; but, in practice, a *complete* exhaustion of the mixed mass is hardly probable.

M. Salvetat, who has studied the *vert de Guignet*, assumes the formation to be a double compound of potassic borate and chromic borate.

Finding that the precise composition of this compound was thus, in fact, unknown, and that no complete analysis of it was extant, Dr. Hofmann was led to request Mr. Shipton, a young chemist working in his laboratory, to analyse the specimen exhibited in 1862 by M. Kestner, and placed by that gentleman at Dr. Hofmann's disposal.

The presence of boracic acid in this specimen was at once unmistakably indicated by the appearance of the characteristic green-edged flame, when a portion of it was exposed on a piece of platinum-foil, to the action of a strong red heat.

Dried at 100° Cent. the substance lost a small percentage of water (from 7·43 to 7·46 per cent.), which loss was increased by ignition. As, however, the determination of water by ignition would, in this case, have been attended with uncertainty, seeing that the partial transformation of the sesquioxide into the binoxide of chromium would have caused the percentage of water expelled to appear less than it really is, Mr. Shipton determined the water directly by strongly heating a portion, dried at 100° Cent. in a current of air, and collecting, in a chloride of calcium tube, the water thus evolved. The chromium was converted by fusion into chromic acid, and the latter determined in the form of chromate of lead. The boracic acid, lastly, was estimated by difference as loss.

Mr. Shipton arrived in this manner at the following percentages:—

Composition of Vert de Guignet after having been dried at 100° Cent.

	I.	II.	Mean.
Oxide of chromium	76·39	76·56	76·47
Boracic acid	11·89	12·30	12·10
Water	11·72	11·14	11·43
	100·00	100·00	100·00

MOCHA STONE. See AGATE.

MOHAIR is the hair of a goat which inhabits the mountains in the vicinity of Angora, in Asia Minor.

We are indebted for this account of mohair to the 'History of the Worsted Manufacture of England,' by James.

Very much akin to, and in Yorkshire rising into importance about the same time as that of alpaca, the mohair manufacture demands attention.

The goat is among the earliest animals domesticated by man, and undoubtedly, from the very earliest ages, the fabrication of stuffs from its hair was practised by the nations of antiquity. Throughout the middle ages the art of making beautiful stuffs from the covering of the goat prevailed.

After the Angora goats have completed their first year, they are clipped annually, in April and May, and yield progressively from 1 lb. to about 4 lbs. weight of hair. That of the female is considered better than the male's, but both are mixed together for the market, with the exception of the *two-year-old she-goat's fleece,* which is kept with the picked hair of other white goats (of which, perhaps, 5 lbs. may be chosen out of 1,000), for the native manufacture of the most delicate articles; none being ever exported in any unwrought state. Common hair is sold in the Angora bazaar for 9 piastres, or about 1*s.* 8½*d.* the oke (that is, 2¾ lbs.), whilst the finest picked wool of the same growth fetched 14 piastres the oke. When the fleeces are shorn, the women separate the clean hair from the dirty, and the latter only is washed, after which the whole is mixed together, and sent to the market. That which is not exported raw is bought by the women of the labouring families, who, after pulling portions loose with their fingers, pass them successively through a large and fine toothed comb, and spin it into skeins of yarn, of which six qualities are made. An oke of Nos. 1 and 3 fetched in the Angora bazaar from 24 to 25 piastres, and the like weight of Nos. 3 to 6 from 38 to 40 piastres. Threads of the first three Nos. had been usually sent to France, Holland, and Germany; those of the last three qualities to England. The women of Angora moisten the hair with much spittle before they draw it from the distaff, and they assert that the quality of the thread greatly depends upon this operation.

Formerly there was a prohibition against the export from Turkey of the Angora hair except when wrought, or in the form of homespun yarn; but about the time of the Greek revolution, this prohibition was removed. Up to that period, however, there had been little demand for the raw material in Europe, so that it sold in the year 1820 at only 10*d.* per pound in England. The reason of the raw material not being in request arose from the belief that, owing to the peculiarity of the fibre, it could not be spun by machinery. It soon, however, became apparent that mohair could be thus spun in England, and this was to be more desired, because the Angora spun-yarn had so many imperfections, from being thick and uneven, as to detract greatly from its value. This object, however, has been obtained, mainly by the perseverance of Mr. Southey, the eminent London wool-broker. Since then the use of the Angora wool has much extended, whilst the importation has much decreased, the English spun-yarn being preferred.

The demand for Angora hand-spun yarn has almost ceased, and its value in Turkey has fallen to one-half. Mohair is transmitted to England chiefly from the ports of Smyrna and Constantinople. In colour it is the whitest known in the trade, and is, consequently, peculiarly adapted for the fabrication of a certain class of goods. Besides Angora, quantities of an inferior sort of mohair are received from other parts of Asiatic Turkey; a very fine description of goat's hair is also sent from that country.

In England mohair is mostly spun, and to some extent manufactured, at Bradford, and also, in a less degree, spun at Norwich. Scotland is also engaged in working up mohair-yarn. At first great difficulty occurred in sorting and preparing the material for spinning, but by patient experiment this has been effectually surmounted, and a fine and even thread produced, fitted for the most delicate webs.

The price of Angora goat's hair has, since its importation into this country, fluctuated very much, partly from the variations in demand, and partly owing to the supply.

The *Importation* of goat's hair or wool—which will include mohair—in 1873 was as follows:—

	lbs.	Value
From Turkey	6,006,016	£752,621
„ British Possessions in South Africa .	348,266	23,850
„ Other countries	133,900	12,535
Total	6,488,182	£789,006

Numerous articles are manufactured from mohair. For instance, many kinds of camblets, which, when watered, exhibit a beauty and brilliancy of surface unapproached by fabrics made from English wools. It is also manufactured into plush, as well as for coach and decorative laces, and also extensively for buttons, braidings, and other trimmings for gentlemen's coats. Besides, it is made up into a light and fashionable cloth, suitable for paletots and such-like coats, combining elegance of texture with the advantages of repelling wet. A few years since, mohair striped and checked textures, for ladies' dresses, possessing unrivalled glossiness of appearance, were in request; but of late these have been superseded by alpaca. For many years the export of English mohair-yarn has been considerable to France.

The trade is enjoyed by Bradford and Norwich, but chiefly by the former place. This yarn is manufactured in France into a kind of lace, which, in a great measure, is substituted for the costly fabrics of Valenciennes and Chantilly. The Angora goat's-hair lace is as brilliant as that made from silk, and costing only about 1*s.* 2*d.* the piece, has come into very general wear among the middle classes. Mohair is also manufactured into fine shawls, selling from 4*l.* to 16*l.* each. Also large quantities of what is termed Utrecht velvet, suitable for hangings and furniture-linings for carriages, are made from it abroad. Recently, this kind of velvet has begun to be manufactured at Coventry, and it is fully anticipated that the English-made article will successfully compete with the foreign one in every essential quality.

MOIRE is the name given to the best watered silks. These silks are made in the same way as ordinary silks, but always much stouter, sometimes weighing, for equal surface, several times heavier than the best ordinary silks. They are always made of double width, and this is indispensable in obtaining the bold waterings, for these depend not only on the quality of the silk, but greatly on the way in which they are folded when subjected to the enormous pressure in watering. They should be folded in such a manner, that the air which is contained between the folds of it should not be able to escape easily; then when the pressure is applied the air, in trying to effect its escape, drives before it the little moisture which is used, and hence causes the watering. Care must also be taken so to fold it that every thread may be perfectly parallel, for if they ride one across the other, the watering will be spoiled. The pressure used is from 60 to 100 tons.

MOIRÉE MÉTALLIQUE, called in this country crystallised tin-plate, is a variegated primrose appearance, produced upon the surface of tin-plate, by applying to it in a heated state some dilute nitro-muriatic acid for a few seconds, then washing it with water, drying, and coating it with lacquer. The figures are more or less beautiful and diversified, according to the degree of heat, and relative dilution of the acid. This mode of ornamenting tin-plate is much less in vogue now than it was a few years ago.

MOLASSE is a sandstone belonging to the miocene strata, employed under that name by the Swiss for building.

MOLASSES is the brown viscid uncrystallisable liquor which drains from cane-sugar in the colonies. It is employed for the preparation of spirits of wine. See SUGAR.

MOLYBDENUM (*Molybdène*, Fr.; *Molybdän*, Ger.) is a rare metal which occurs in nature sometimes as a sulphide, sometimes as molybdic acid, and at others as molybdate of lead. Its reduction from the acid state by charcoal requires a very high heat, and affords not very satisfactory results. When reduced by passing hydrogen over the ignited acid, it appears as an ash-grey powder, susceptible of acquiring metallic lustre by being rubbed with a steel burnisher; when reduced and fused with charcoal, it possesses a silver-white colour, is very brilliant, hard, brittle, of specific gravity 8·6; it melts in a powerful air-furnace, oxidises with heat and air, burns at an intense heat into molybdic acid, dissolves in neither dilute sulphuric, muriatic, nor fluoric acids, but in the concentrated sulphuric and nitric.

The protoxide consists of 85·69 of metal and 14·31 of oxygen; the binoxide consists of 75 of metal and 25 of oxygen; and the peroxide, or molybdic acid, of 66·6 of metal and 33·4 of oxygen. This metal is too rare at present to be used in any manufacture.

MOLYBDENUM BLUE. One of the preparations from the bisulphide of molybdenum.

MOMIE or **MUMMY.** A colour prepared from asphalte. It was supposed that the asphalte taken from the Egyptian mummies made the finest colour.

MOONSTONE, a transparent or translucent variety of felspar. It contains bluish-white spots, which, when held to the light, present a pearly or silvery play of colour, not unlike that of the moon. The moonstone is held in some estimation as an ornamental stone, but, in common with the other varieties of felspar, it is so soft that few lapidaries know how to work it to the greatest advantage.—H. W. B.

MORDANT, in dyeing and calico-printing, denotes a body which, having a twofold attraction for organic fibres and colouring particles, serves as a bond of union between them, and thus gives fixity to certain colouring substances, constituting them dyes. In order properly to appreciate the utility and the true functions of mordants, we must bear in mind that many colouring matters, even those forming dark-coloured solutions, have no affinity for the fibre to be dyed. When the goods are passed through such a coloured solution, they become stained only to the extent in which they retain the solution, and if they are afterwards put into water, the colour, being soluble, is all washed out. Suppose the coloured solution to be a decoction of logwood, and that the stuff is passed into it. It may be slightly coloured; but on being washed with water, all the colour is removed. But if, previous to being put through the logwood solution, the stuff be passed through a solution of protochloride of tin, a portion of the tin is retained by it, in virtue of an influence (a condition of capillarity) between the fibre and the salt. There will now be formed a beautiful wine-coloured compound, between the logwood and the tin upon the goods, when they are placed in the logwood-bath, which washing with water will not remove, the compound being insoluble. The tin in this case constitutes the mordant. It is not always essential that the mordant be put upon the fibre previous to being put into the coloured solution; they may be mixed together, and the goods placed in the mixture, when much of the coloured compound will combine with or adhere to the fibre; but, in general, this mode of applying the mordant is not so effective. If, as is usually said, the mordant enters into a real chemical union with the stuff to be dyed, the application of the mordant should obviously be made in such circumstances as are known to be most favourable to the combination taking place; and this is the principle of every day's practice in the dye-house.

Mordants are in general found among the metallic bases or oxides; whence they might be supposed to be very numerous, like the metals; but as they must unite the twofold condition of possessing a strong affinity for both the colouring-matter and the organic fibre, and as the insoluble bases are almost the only ones fit to form insoluble combinations, we may thus perceive that their number may be very limited. It is well known, that although lime and magnesia, for example, have a considerable affinity for colouring particles, and form insoluble compounds with them, yet they cannot be employed as mordants, because they possess no affinity for the textile fibres.

It will be observed from the above remarks, that the mordant serves a higher purpose than the mere bond of union between the colour and fibre; that it, in fact, constitutes a principal element in the colour. The colour forming the dye, in the case with the logwood and tin, is not that of hæmatoxylin, the colouring-matter of logwood; but of the compound formed between it and tin, and thus logwood, by different mordant bases, gives a variety of colours, from a grey to a black, and from a light lavender to a deep purple, &c. When an organic colouring-matter is imparted to any fibre without the intervention of a mordant, it can only produce one tint, which cannot be varied except in being light and dark.

Experience has proved, that of all the bases, those which succeed best as mordants are alumina, tin, and oxide of iron.

Blue-black dye.—The mordant much employed in some parts of Germany for this dye, with logwood, galls, sumach, &c., is *Iron-alum*, so called on account of its having the crystalline form of alum, though it contains no alumina. It is prepared by dissolving 78 pounds of red oxide of iron in 117 pounds of sulphuric acid, diluting this compound with water, adding to the mixture 87 pounds of sulphate of potash, evaporating the solution to the crystallising point. This potassa-sulphate of iron has a fine amethyst colour when recently prepared; and though it gets coated in the air with a yellowish crust, it is none the worse on this account. As a mordant, a solution of this salt, in from 6 to 60 parts of water, serves to communicate and fix a great variety of uniform ground colours, from light grey to brown, blue, or jet black, with quercitron, galls, logwood, sumach, &c., separate or combined. The above solution may be usefully modified by adding to every 10 pounds of the *iron-alum*, dissolved in 8 gallons (80 pounds) of warm water, 10 pounds of acetate (sugar) of lead, and leaving the mixture, after careful stirring, to settle. Sulphate of lead falls, and the oxide of iron remains combined with the acetic acid and the potash. After passing through the above mordant, the cotton goods should be quickly dried.

Colours of the above class are, however, mostly insoluble in water, and have to be dissolved or extracted by an alkaline solvent: and in this state have no affinity either for the fibre or a mordant. Safflower is an instance of this kind; the red colouring-matter of this vegetable is extracted by a weak alkaline lye, into which the goods to be dyed are afterwards put; and the alkali being neutralised by an acid, the colouring-matter is thus rendered insoluble in the liquor, in a state of minute division, and is gradually absorbed by the fibre, which becomes dyed of a red colour in depth according to the quantity of colour absorbed.

Indigo is another dye of this sort requiring an alkaline solvent, and not dyed with mordants. (See DYEING.)

The following remarks will illustrate some of the necessary requirements of a mordant, which should be attended to by the dyer, in their application.

In order that a combination may result between two bodies, they must not only be in contact, but they must be reduced to their ultimate molecules. The mordants that are to be united with stuffs are, as we have seen, insoluble of themselves, for which reason their particles must be divided by solution in an appropriate vehicle. Now this solvent or menstruum will exert in its own favour an affinity for the mordant, which will prove, to that extent, an obstacle to its attraction for the stuff. Hence we must select such solvents as have a weaker affinity for the mordants than the mordants have for the stuffs. Of all the acids which can be employed to dissolve alumina, for example, vinegar is the one which will retain it with least energy, for which reason the acetate of alumina is now generally substituted for alum, because the acetic acid gives up the alumina with such readiness that mere elevation of temperature is sufficient to effect the separation of these two substances. Before this substitution of the acetate, alum alone was employed; but without knowing the true reason, all the French dyers preferred the alum of Rome, simply regarding it to be purest; and it is not many years since they have understood the real grounds of this preference. This alum has not, in fact, the same composition as the alums of France, England, and Germany, but it consists chiefly of cubic alum having a larger proportion of base. Now this extra portion of base is held by the sulphuric acid more feebly than the rest, and hence it is more readily detached in the form of a mordant. Nay, when a solution of cubic alum is heated, this redundant alumina falls down in the state of a subsulphate, long before it reaches the boiling point. This difference had not, however, been recognised, because Roman alum, being usually soiled with ochre on the surface, gives a turbid solution, whereby the precipitate of subsulphate of alumina escaped observation. When the liquid was filtered, and crystallised afresh, common octahedral alum alone was obtained; whence it was most erroneously concluded, that the preference given to Roman alum was unjustifiable, and that its only superiority was in being freer from iron. See Alum.

Here a remarkable anecdote illustrates the necessity of extreme caution, before we venture to condemn from theory a practice found to be useful in the arts, or set about changing it. When the French were masters in Rome, one of their ablest chemists was sent thither to inspect the different manufactures, and to place them upon a level with the state of chemical knowledge. One of the fabrics, which seemed to him furthest behindhand, was precisely that of alum, and he was particularly hostile to the construction of the furnaces, in which vast boilers received heat merely at their bottoms, and could not be made to boil. He strenuously advised them to be modelled upon a plan of his own; but, notwithstanding his advice, which was no doubt very scientific, the old routine kept its ground, supported by utility and reputation, and very fortunately, too, for the manufacture; for had the higher heat been given to the boilers, no more genuine cubical alum would have been made, since it is decomposed at a temperature of about 120° F., and common octahedral alum would alone have been produced. The addition of a little alkali to common alum brings it into the same basic state as the alum of Rome.

The two principal conditions, namely, extreme tenuity of particles, and liberty of action, being found in a mordant, its operation is certain. But as the combination to be effected is merely the result of a play of affinity between the solvent and the stuff to be dyed, a sort of partition must take place, proportioned to the mass of the solvent, as well as to its attractive force. Hence the stuff will retain more of the mordant when its solution is more concentrated, that is, when the base diffused through it is not so much protected by a large mass of menstruum; a fact applied to very valuable uses by the practical man. On impregnating in calico-printing, for example, different spots of the same web with the same mordant in different degrees of concentration, there is obtained in the dye-bath a depth of colour upon these spots intense in proportion to the strength of their various mordants. Thus, with the solution of acetate of alumina in different grades of density, and with madder, every shade can be produced, from the fullest red to the lighest pink; and, with acetate of iron and madder, every shade from black to pale violet.

We hereby perceive that recourse must indispensably be had to mordants at different stages of concentration: a circumstance readily realised by varying the proportions of the watery vehicle. (See Calico-Printing and Madder.) When these mordants are to be topically applied, to produce partial dyes upon cloth, they must be thickened with starch or gum, to prevent their spreading, and to permit a sufficient body of them to become attached to the stuff. Starch answers best for the more neutral mordants, and gum for the acidulous; but so much of them should never be used as to impede the attraction of the mordant for the cloth. Nor should the thickened mordants be of too desiccative a nature, lest they become hard, and imprison the chemical agent before it has had an opportunity of combining with the cloth, during the slow evaporation of its water and acid. Hence the mordanted goods, in such a case, should be hung up to dry in a gradual manner, and when oxygen is necessary to the fixation of the base, they should be largely exposed to the atmosphere. The foreman of the factory ought, therefore, to be thoroughly conversant with all the minutiæ of chemical reaction. In cold and damp weather he must raise the temperature of his drying-house, in order to command a more decided evaporation; and when the atmosphere is unusually dry and warm, he should add deliquescent correctives to his thickening. But, supposing the application of the mordant and its desiccation to have been properly managed, the operation is by no means complete; nay, what remains to be done is not the least important to success, nor the least delicate of execution. Let us bear in mind that the mordant is intended to combine not only with the organic fibre, but afterwards also with the colouring-matter, and that, consequently, it must be laid entirely bare, or scraped clean, so to speak, that is, completely disengaged from all foreign substances which might invest it, and obstruct its intimate contact with the colouring-matters. This is the principle and the object of two operations, to which the names of *dunging* and *clearing* have been given. See Calico-Printing.

If the mordant applied to the surface of the cloth were completely decomposed, and the whole of its base brought into chemical union with it, a mere rinsing or scouring in water would suffice for removing the viscid substances added to it but this never happens, whatsoever precautions may be taken; one portion of the mordant remains untouched, and besides, one part of the base of the portion decomposed does not enter into combination with the stuff, but continues loose and superfluous. All these particles, therefore, must be removed without causing any injury to the dyes. If in this predicament the stuff were merely immersed in water, the free portion of the mordant would dissolve, and would combine indiscriminately with all the parts of the cloth not mordanted, and which should be carefully protected from such combination, as well as the action of the dye. We must therefore add to the scouring-water some substance that is capable of seizing the mordant as soon as it is separated from the cloth, and of forming with it an insoluble compound; by which means we shall withdraw it from the sphere of action, and prevent its affecting the rest of the stuff, or interfering with the other dyes. This result is obtained by the addition of cow-dung to the scouring-bath: a substance which contains a sufficiently large proportion of soluble animal matters, and of colouring particles, for absorbing the aluminous and ferruginous salts. The heat given to the dung-bath accelerates this combination, and determines an insoluble and perfectly inert coagulum.

Thus the dung-bath produces at once the solution of the thickening paste; a more intimate union between the alumina or iron and the stuff, in proportion to its elevation of temperature, which promotes that union; an effectual subtraction of the undecomposed and superfluous part of the mordant, and perhaps a commencement of mechanical separation of the particles of alumina, which are merely dispersed among the fibres; a separation, however, which can be completed only by the proper scouring, which is done by the dash-wheel with such agitation and pressure (see Bleaching) as vastly facilitate the expulsion of foreign particles.

Before concluding this article, we may say a word or two about astringents, and especially gall-nuts, which have been ranked by some writers among mordants. It is rather difficult to account for the part which they play. Of course we do not allude to their operation in the black dye, where they give the well-known purple-black colour with salts of iron; but to the circumstance of their employment for a variety of dyes, and also of dye-drugs, as sapan and Brazil-wood, madder, and logwood, and especially in the dye Adrianople or Turkey red. All that seems to be clearly established is, that the astringent principle or tannin, whose peculiar nature in this respect is unknown, combines like mordants with the stuffs, and fixes a greater quantity of the base upon it, and thus adds depth to the colour, as well as certain peculiarities of tint; but as this tannin has itself a brown tint, it will not suit for white grounds, though it answers quite well for pink grounds. When white spots are desired upon a cloth prepared with oil and galls, they are produced by an oxygenous discharge, effected either through chlorine or chromic acid. See Calico-Printing, and the various Mordants there particularised under their respective heads.—J. N.

MOREEN. A stout woollen stuff, which is chiefly employed for curtains.

MORINDA CITRIFOLIA. This was first imported into Glasgow, from India, some years ago. It occurs in pieces of from 2 to 8 centimeters in length, and from 5 to 10 millimeters thick. Externally it is brown, internally yellow: the pigment, or colouring-matter, is exclusively concentrated in the bark; its colour is orange-yellow, and it has been named *morindin.*

The morindin is extracted from the root by exhausting with boiling alcohol; on cooling, the colouring-matter is deposited as an impure flocculent material, mixed with a red substance. This crude material is purified by repeated re-crystallisation, first from alcohol at 50 per cent., and finally from stronger alcohol acidulated with hydrochloric acid. Thus obtained, the substance forms satin-like, needle-shaped, yellow crystals. Morindin is sparingly soluble in cold water, more readily in boiling, but is deposited, on cooling, as a gelatinous mass. It is sparingly soluble in alcohol when cold, but readily when boiling, and best in a weaker spirit; it is insoluble in ether. The aqueous solutions are coloured orange by alkalis; lime- and baryta-water yield red precipitates; while acetate of lead forms a crimson precipitate; a mixture of a few drops of ammonia added to perchloride of iron, causes a brown precipitate in the aqueous solution; while ammoniated alum yields a reddish-yellow precipitate. Morindin dissolves in concentrated sulphuric acid with a deep purple-red colour; the solution, after having been kept for 24 hours, yields, on addition of water, a yellow precipitate, insoluble in water, which re-dissolves in ammonia with a violet colouration.

If submitted to the action of heat, morindin first fuses, and then enters into ebullition, emitting beautiful orange-vapours, which condense to beautiful red needle-shaped crystals, insoluble in water, but soluble in alkaline liquids. with a violet colour. This substance, which Dr. Anderson calls morindin, seems to be the same as that formed under the influence of sulphuric acid. The ammoniacal solution of morindin yields, with alum, a red lake, and gives, upon the addition of baryta-water, a blue precipitate. Morindin is dissolved by cold nitric acid, and decomposed by that liquid at boiling temperature. See Aal.

MORINE. This is the name given by Gerhardt to the principal colouring-matter of the *Morus tinctoria* or *old fustic*, a large tree which grows in many parts of the West Indies, and on the American Continent. It is used principally for dyeing woollens or silks, seldom or ever as a solitary colour, but as a ground-work for other colours, as in the dyeing of wools and silks black, in which process it greatly improves the black. It is used with indigo to form a green, and with salts of iron to yield an olive hue. The colouring-matter was first separated by Chevreul. It is extracted from the wood by boiling water, which, on cooling, when concentrated, deposits it as yellow crystalline powder, which must be purified by several crystallisations. It has the composition $C^{36}H^{16}O^{20}$ ($\mathbf{C^{18}H^{16}O^{10}}$). It possesses a sweetish and astringent taste; one part dissolves in 6·4 parts of cold water, and in 2·14 parts of boiling water. The solution is slightly acid, and precipitates salts of iron of a dark green colour; with salts of lead and protochloride of tin, it forms deep yellow precipitates. It is not precipitated by alum until after the addition of carbonate of potash, when a yellow lake is formed.

Concentrated sulphuric acid dissolves it in the cold, forming a yellow solution, from which it is again precipitated by diluting with water. It is readily soluble in alcohol and ether; insoluble in spirits of turpentine and the fatty oils. Alkalis deepen the colour of its solutions. See Fustic.

MORINGA. The seeds of the *Moringa pterygosperma* have been used for the oil they contain. These have been examined and reported on by Mr. Dugald Campbell, who says of the oil they yield:—'This oil is the very opposite to a dry oil, being extremely rich in fatty substances, and is of specific gravity 915·60 at 60° Fahr., water taken as 1·000. When it is kept cooled for a short time to 44° it becomes opaque, from crystals of the fatty substances forming throughout it, and it is now very viscid and thick. In this state it may be heated up to 65° before it assumes its original brightness. It is nearly tasteless, and almost without odour.' This oil is called *Oil of Ben*, and is much used by watchmakers. See Ben Oil.

MOROCCO. See Leather.

MORPHINE. *Syn.* Morphia. (*Morphine*, Fr.; *Morphin*, Ger.) $C^{34}H^{19}NO^{6} + 2\,aq.$ ($\mathbf{C^{17}H^{19}NO^{3} \,.\, H^{2}O}$). An organic base, contained (amongst others) in opium. As it is the substance upon which the sedative properties of opium depend, great attention has been paid to its extraction. Numerous processes have been devised for the purpose; but perhaps that of Gregory is, in facility and economy, as good as any. The aqueous infusion is precipitated by chloride of calcium to remove the meconic and sulphuric acids present. The filtered fluid is evaporated until the hydrochlorate of morphine crystallises out, so as to form a nearly solid mass, which is then strongly pressed: the liquid exuding contains the colouring-matters and several alkaloïds. The pressed mass is crystallised and squeezed repeatedly, and, if necessary, bleached with animal charcoal. The hydrochlorate, which contains a little codeine, is to be dissolved in water, and precipitated by ammonia; pure morphia precipitates, and the codeine remains in solution. The salts of morphia most employed in medicine are the hydrochlorate, the acetate, and the sulphate. A solution of five grains of morphia in one ounce of water is about the same strength as laudanum. *Apomorphia* is a remarkable base, obtained by Matthiessen and Wright by heating morphia for several hours in a closed tube with excess of hydrochloric acid. It may also be prepared, by a similar method, from codeine. Apomorphia differs from morphia in containing $H^{2}O^{2}$ ($\mathbf{H^{2}O}$) less; its formula is therefore $C^{34}H^{17}NO^{4}$ ($\mathbf{C^{17}H^{17}NO^{2}}$).

MORTAR. A mixture of lime with water and sand. The sand used in making mortar should be *sharp*—that is angular, not round—and *clean*—that is, free from all earthy matter, or other than siliceous particles. Hence *road-scrap-*

ings always, as being a mixture of sand and mud, and *pit-sand* generally, as being scarcely ever without a portion of clay, should be washed before they are used; which is seldom necessary with *river-sand*, this being cleaned by the flowing water.

'I have ascertained by repeated experiments that 1 cubic foot of well-burned chalk-lime fresh from the kiln, weighing 35 lbs., when well mixed with 3½ cubic feet of good river-sand, and about 1⅓ cubic foot of water, produced above 3¼ cubic feet of as good mortar as this kind of lime is capable of forming. A smaller proportion of sand, such as two parts to one of lime, is, however, often used, which the workmen generally prefer; both because it requires less time and labour in mixing, which saves trouble to the labourers, and it also suits the convenience of the masons and bricklayers better, being what is termed *tougher*, that is, more easily worked, but it does not by any means make such good mortar. If, on the other hand, the sand be increased to more than the above proportion of 3½, it renders the mortar *too short*, that is, not plastic enough for use, and causes it also to be too friable, for excess of sand prevents mortar from setting into a compact adhesive mass. In short, there is a certain just proportion between these two ingredients which produces the best mortar, which I should say ought not to be less than 3, nor more than 3½, parts of sand to 1 of lime; that is when common chalk-lime, or other pure limes, are used, for different limes require different proportions. When the proportion of sand to lime is stated in the above manner, which is done by architects as a part of their specification or general directions for the execution of a building, it is always understood, when nothing is expressed to the contrary, that the parts are by fair level measure of the lime, and by stricken measure for the sand; and the lime is to be measured in lumps, in the same state in which it comes from the kiln, without slaking, or even breaking it into smaller pieces.'—*Pasley.*

MORTAR, HYDRAULIC, is the kind of mortar used for building piers or walls under or exposed to water, such as those of docks, &c. See HYDRAULIC CEMENT.

MOSAIC. (*Mosaïque*, Fr.; *Mosaisch*, Ger.) There are several kinds of mosaic, but all of them consist in imbedding fragments of differently-coloured substances, usually glass or stones, in a cement, so as to produce the effect of a picture. The beautiful chapel of Saint Lawrence in Florence, which contains the tombs of the Medici, has been greatly admired by artists on account of the vast multitude of precious marbles, jaspers, agates, aventurines, malachites, &c., applied in mosaic upon its walls. The detailed discussion of this subject belongs to a treatise upon the fine arts, but the progress of the invention is so curious that some brief notice of mosaic-work in general will not be out of place.

When, with his advancing intelligence, man began to construct ornamental articles to decorate his dwelling, or to adorn his person, we find him taking natural productions, chiefly from the mineral kingdom, and combining them in such a manner as will afford, by their contrasts of colour, the most pleasing effects. From this arose the art of mosaic, which appears, in the first instance, to have been applied only to the combination of dice-shaped stones (*tesseræ*) in patterns. This was the *opus musivum* of the Romans; improving upon which, we have the Italians introducing the more elaborate and artistic *pietra dura*, now commonly known as Florentine work. It is not our purpose to treat of any of the ancient forms of mosaic-work, further than it is necessary to illustrate the subject before us. The *opus tesselatum* consisted of small cubes of marble, worked by hand into simple geometrical figures. The *opus sectile* was formed of different crusts or slices of marble, of which figures and ornaments were made. The *opus vermiculatum* was of a far higher order than these: by the employment of differently-coloured marbles, and, where great brilliancy of tint was required, by the aid of gems, the artists produced imitations of figures, ornaments, and pictures, the whole object being portrayed in all its true colours and shades.

The advance from the *opus vermiculatum* to the fine mosaic-work, which had its origin in Rome, and is, therefore, especially termed Roman mosaic, was easy; and we find this delicate manufacture arising to a high degree of excellence in the city where it originated, and to which it has been almost entirely confined, Venice being the only city which has attempted to compete with Rome. To this art-manufacture we more especially direct attention, since a description of it will aid us in rendering intelligible the most interesting and peculiarly novel manufacture of mosaic rug-work, as practised by the Messrs. Crossleys. Roman, and also Venetian enamels, are made of small rods of glass, called indiscriminately *paste* and *smalt*. In the first place, cakes of glass are manufactured in every variety of colour and shade that are likely to be required. These cakes are drawn out into rods more or less attenuated, as they are intended to be used for finer or for coarser work, a great number being actually threads of glass. These rods and threads are kept in bundles, and arranged in sets corresponding to their colours, each division of a set presenting every desired shade. A piece of dark slate or marble is prepared, by being hollowed out like a box, and this is filled with plaster-of-Paris. Upon this plaster the pattern is drawn by the artist, and the *mosaicisti* proceeds with his work by removing small squares of the plaster, and filling in these with pieces cut from the rods of glass. Gradually, in this manner, all the plaster is removed, and a picture is formed by the *ends of the filaments of coloured glass*; these are carefully cemented together by a kind of mastic, and polished. In this way is formed, not only those exquisitely delicate mosaics which were, at one time, very fashionable for ladies' brooches, but tolerably large and often highly-artistic pictures. Many of our readers will remember the mosaic landscapes which rendered the Italian Court of the Great Exhibition so attractive; and in the Museum of Practical Geology will be found a portrait of the late Emperor of Russia, which is a remarkably good illustration of mosaic-work on a large scale. We may remark, in passing, that the whole process of glass-mosaic is well illustrated in this collection.

The next description of mosaic-work requiring a word is the manufacture of Tunbridge. The wood-mosaics of Tunbridge are formed of rods of wood, varying in colour, laid one upon the other, and cemented together, so that the pattern, as with the glass-mosaics, is produced by the ends of the rods.

MOSAIC GOLD. For the composition of this peculiar alloy of copper and zinc, called also *Or-molu*, Messrs. Parker and Hamilton obtained a patent in November 1825. Equal quantities of copper and zinc are to be 'melted at the lowest temperature that copper will fuse,' which, being stirred together so as to produce a perfect admixture of the metals, a further quantity of zinc is added in small portions, until the alloy in the melting-pot becomes of the colour required. If the temperature of the copper be too high, a portion of the zinc will fly off in vapour, and the result will be merely spelter or hard solder; but if the operations be carried on at as low a heat as possible, the alloy will assume first a brassy-yellow colour; then, by the introduction of small portions of zinc, it will take a purple or violet hue, and will ultimately become perfectly white, which is the appearance of the proper compound in its fused state. This alloy may be poured into ingots; but as it is difficult to preserve its character when re-melted, it should be cast directly into the figured moulds. The patentees claim exclusive right of compounding a metal consisting of from 52 to 55 parts of zinc, out of 100.

Mosaic gold, the *aurum musivum* of the old chemists, is a sulphuret of tin. See ALLOYS.

MOSAIC WOOL-WORK. There is no branch of manufacture which is of a more curious character than the mosaic wool-work of the Messrs. Crossleys of Halifax.

By referring to the article MOSAIC there will be no difficulty in understanding how a block of wood, which has been constructed of hundreds of lengths of coloured specimens, will, if cut transversely, produce a great number of repetitions of the original design. Suppose, when we look at the transverse section presented by the end of a Tunbridge block, we see a very accurately-formed geometric pattern; this is rendered perfectly smooth, and a slab of wood is glued to it. When the adhesion is secure, as in a piece of veneering for ordinary cabinet-work, a very thin slice is cut off by means of a circular saw, and then we have the pattern presented to us in a state which admits of its being fashioned into any article which may be desired by the cabinet-maker. In this way, from one block, a very large number of slices can be cut off, every one of them presenting exactly the same design. If lengths of worsted are substituted for those of glass or of wood, it will be evident that the result will be in many respects similar. By a process of this kind the mosaic rugs—with very remarkable copies from the works of some of our best artists—are produced. In connection with this manufacture, a few words on the origin of this kind of work will not be out of place.

The tapestries of France have been long celebrated for the artistic excellence of the designs, and for the brilliancy and permanence of the colours. These originated in France, about the time of Henry IV., and the manufacture was much patronised by that monarch and his minister Sully. Louis XIV. and Colbert, however, were the great patrons of the beautiful productions of the loom. The minister of Louis bought from the brothers Gobelins their manufactory, and transformed it into a royal establishment, under the title of *Le Teinturier Parfait.* A work was published in 1746 in which it was seriously told that the dyes of the Gobelins had acquired such superiority that their contemporaries attributed the talent of these celebrated artists to a paction which one or the other of them had made with the devil.

In the Gobelins and Beauvais tapestry we have examples of the most artistic productions, executed with a *mechanical* skill of the highest order, when we consider the material in which the work is executed. The method of manufacture, involving artistic power on the part of the workman, great manipulatory skill, and the expenditure of much time, necessarily removes those productions from the reach of any but the wealthy. Various attempts have been made, from time to time, to produce a textile fabric which should equal those tapestries in beauty, and which should be sold to the public at much lower prices. None of these appear to have been successful, until the increasing applications of india-rubber pointed to a plan by which high artistic excellence might be combined with moderate cost. In Berlin, and subsequently in Paris, plans (in most respects similar to the plan we are about to describe) were tried, but in neither instance with complete success. Of course, there cannot now be many of our readers who have not been attracted by the many life-like representations of lions and dogs which have for the last few years been exhibited in the carpet-warehouses of the metropolis, and other large cities. While we admit the perfection of the manufacture, we are compelled to remark that the designs which have been chosen are not such as appear to us to be quite appropriate, when we consider the purposes for which a rug is intended. However, from their very attractive character and moderate cost, those rugs find a large number of purchasers, by whom they are doubtless greatly admired. It will, however, be obvious to our readers, that they are not consistent with the principles of design, and that there is a want of consistency in the idea of treading upon the 'monarch of the forest,' copied with that remarkable life-likeness which distinguishes the productions of Sir Edwin Landseer; or in placing one's feet in the midst of dogs or of poultry, when the resemblances are sufficiently striking to impress you with the idea that the dogs will bark and that the cock will crow. We believe that less picturesque subjects, in accordance with the law—which we conceive to be the true one—which gives true beauty only to that which is, in its applications, consistent and harmonious, would be yet greater favourites than those rugs now manufactured by the Messrs. Crossleys. And amidst the amount of good which these excellent men are doing to all who come within their influence, we are certain they might, with the means at their command, introduce an arrangement of colours which might delight by their harmonious blending, and a system of designs which, pure and consistent, should ever charm the eye, without attempting to deceive either it, or any of the senses. Every attempt to advance the taste of a people is worthy of all honour; and having the power, as the manufacturers of the mosaic rugs have, of producing works of the highest artistic excellence, we should be rejoiced to see them employing that power to cultivate amongst all classes a correct perception of the true and the beautiful.

With these remarks we proceed to a description of the manufacture.

Every lady who has devoted herself for a season, when it was the fashion to do so, to Berlin wool-work, will appreciate the importance of a careful arrangement of all the coloured worsteds which are to be used in the composition of her design. Here, where many hundreds of colours, combinations of colours, and shades are required, in great quantities and in long lengths, the utmost order is necessary; and the system adopted in this establishment is in this respect excellent. We have, for example, grouped under each of the primary colours, all the tints of each respective colour that the dyer can produce, and between each large division the mixtures of colour producing the neutral tones, and the interblending shades which may be required to copy the artist with fidelity. Skeins of worsted thus arranged are ever ready for the English *mosaicisti* in rug-work. Such is the material. Now to describe the manner of proceeding. In the first place an artist is employed to copy, of the exact size required for the rug, a work of Landseer's, or any other master, which may be selected for the purpose. Although the process of copying is in this case mechanical, considerable skill is required to produce the desired result. This will be familiar to all who have observed the peculiar characteristics of the Berlin wool-work patterns. The picture being completed, it is ruled over in squares, each of about twelve inches. These are again interruled with small squares, which correspond with the threads of which the finished work is to consist. This original being completed, it is copied upon lined paper by girls who are trained to the work, each girl having a square of about twelve inches to work on. These are the copies which go into the manufactory. A square is given to a young woman whose duty it is to match all the colours in wool. This is a task of great delicacy, requiring a very fine appreciation of colour. It becomes necessary in many cases to combine two threads of wool, especially to produce the neutral tints. It is very interesting to observe the care with which every variety of colour is matched. The skeins of worsted are taken, and a knot or knob being formed so as to increase the quantity of coloured surface, it is brought down on the coloured picture; and when the right shades have been selected, they are numbered, and a corresponding system of numbers are put on the pattern. In many of the rugs one hundred colours are employed. The selector of colours works under the guidance of a master, who was in this case a German gentleman, and to his obliging and painstaking kindness we are much indebted. Without his very exact description of every stage of the process, it would not have been easy to render this rare mosaic-work intelligible to our readers. When all the coloured wools have been selected, they are handed, with the patterns, to young women, who are termed the 'mistresses of a frame,' each one having under her charge three little girls.

The 'frame' consists of three iron stands, the two extreme ones being about 200 inches apart, and the other exactly in the middle. These stands are made of stout cast iron, and may be said to consist of two bowed legs, with two cross pieces of iron, one at the top of the legs, and the other about fifteen inches below, the space between them being that which is to be occupied by the threads of wool which are to form the required square block of wool. These frames are united together by means of cast-iron tubes, running from end to end. The observer is struck with the degree of strength which has been given to these frames. It appears that, for the purpose of merely holding together a few threads of wool, a much slighter frame might have been employed; and we certainly were surprised when we were informed that, at first, many frames were broken, and that they were compelled to have the stronger ones at present in use. The cause of this will be obvious, when we have proceeded a little further with our description. At one end of these frames sits the 'mistress,' with a stand before her, on which the pattern allotted to her is placed, and a vertical frame, over which the long coloured worsteds are arranged. By the side of this young woman sits a little girl, who receives each worsted from the mistress, and hands it to one of two children, who are on either side of the frame.

Commencing at one corner of the pattern, a thread is selected of the required colour, and handed to the first girl, who passes it to the second, whose duty it is to fasten it to a stiff, but slight bar of steel, about half an inch in width, which passes from the upper to the under bar of the frame. The third girl receives the thread, and carries it to the lower end of the frame, and fastens it to a similar bar of steel at that end. The length of each thread of worsted is rather more than 200 inches. It is well known that twisted wool does not lie quite straight without some force is applied to it; and of course the finished pattern would be incomplete, if all the threads did not observe the truest parallelism to each other. To effect this, a stretching force equal to four pounds is required to every thread. The child who carries the thread, therefore, pulls the worsted with this degree of force, and fastens it over the steel bar. Every block, forming a foot-square of rug-work, consists of fifty thousand threads; therefore, since every thread pulls upon the frame with a force equal to four pounds, there is a direct strain to the extent of 250,000 pounds upon the frame. When this is known, our surprise is no longer excited at the strength of the iron-work; indeed, the bars of hardened steel, set edgeways, were evidently bent by the force exerted.

Thread after thread, in this way, the work proceeds, every tenth thread being marked by having a piece of white thread tied to it. By this means, if the foreman, when he examines the work, finds that an error has been committed, he is enabled to have it corrected by removing only a few of the threads, instead of a great number, which would have been the case if the system of marking had not been adopted.

This work, requiring much care, does not proceed with much rapidity, and the constant repetition of all the same motions through a long period would become exceedingly monotonous, especially as talking cannot be allowed, because the attention would be withdrawn from the task in hand. Singing has therefore been encouraged, and it is exceedingly pleasing to see so many young, happy, and healthy faces performing a clean and easy task, in unison with some song, in which they all take a part. Harmonious arrangements of colour are produced, under the cheerful influence of harmonious sounds. Yorkshire has long been celebrated for its choristers, and some of the voices which we heard in the room devoted to the construction of the wool-mosaics bore evidence of this natural gift, and of a considerable degree of cultivation.

The 'block,' as it is called, is eventually completed. This, as we have already stated, is about a foot square, and it is 200 inches long. Being bound, so as to prevent the disturbance of any of the threads, the block is cut by means of a very sharp knife into ten parts, so that each division will have a depth of about 20 inches. Hearth-rugs are ordinarily about eight feet long, by about two feet wide, often, however, varying from these dimensions. Supposing, however, this to represent the usual size, twelve blocks, from as many different frames, are placed in a box, with the threads in a vertical position, so that, looking down upon the ends, we see the pattern. These threads are merely sustained in their vertical order by their juxtaposition. Each box, therefore, will contain 800,000 threads. The rug is now, so far as the construction of the pattern is required, completed; and the cost of producing the 'block,' of 200 inches in depth, eight feet in length, and two feet wide, including the cost of wool, and the payment for labour, is little short of 800*l.* When, however, it is known that these threads are subsequently cut into the length required to form the rug, and that these lengths are but the three-sixteenths of an inch in depth, it will be evident that the number of these beautiful carpets which can thus be obtained renders the manufacture fairly remunerative. The boxes into which the rugs are placed are fixed on wheels, and they have moveable bottoms, the object of which will be presently understood. From the upper part of the immense building devoted to carpet manufacture, in which this mosaic rug-work is carried on, we descend with our rug to the basement story. Here we find, in the first place, steam chests, in which india-rubber is dissolved in camphine. It may not be out of place to observe that camphine is actually spirits of turpentine, carefully rectified, and deprived of much of its smell, by being distilled from either potash or soda. Recently-prepared camphine has but little of the terebinthinous odour, but if it is kept long, and especially if it is exposed to the air, it again acquires, with the absorption of oxygen, its original smell. This is of course avoided in the manufacture of such an article as an hearth-rug as much as possible. The camphine is used as fresh as possible, and in it the india-rubber is dissolved, until we have a fluid about the consistence of, and in appearance like, carpenter's glue.

In an adjoining room were numerous boxes, each one containing the rug-work in some of the stages of manufacture. It must now be remembered that each box represents a completed rug—the upper ends of the thread being shaved off, to present as smooth a surface as possible. In every stage of the process now all damp must be avoided, as wool, like all other porous bodies, has a tendency to absorb and retain moisture from the atmosphere. The boxes, therefore, are placed in heated chambers. and they remain there until all moisture is dispelled; when this is effected, a layer of india-rubber solution is laid over the surface, care being taken in the application that every thread receives the proper quantity of the caoutchouc; this is dried in the warm chamber, and a second and a third coat is given to the fibres. While the last coat is being kept in the warm chamber, free from all dust, sufficiently long to dissipate some of the camphine, the surface on which the rug is to be placed receives similar treatment. In some cases ordinary carpet canvas only is employed; in others, a rug made by weaving in the ordinary manner is employed, so that either side of the rug can be turned up in the room in which it is placed. However this may be, both surfaces are properly covered with soft caoutchouc, and the 'backing' is carefully placed on the ends of worsted forming the rug in the box. By a scraping motion, the object of which is to remove all air-bubbles, the union is perfectly effected; it is then placed aside for some little time, to secure by rest that absolute union of parts between the two india-rubber surfaces which is necessary. The separation of the two parts is after this attended with the utmost difficulty; the worsted may be broken by a forcible pull, but it cannot be removed from the india-rubber. The next operation is that of cutting off the rug; for this purpose a very admirable, but a somewhat formidable machine is required. It is in principle, a circular knife, of twelve-feet diameter, mounted horizontally, which is driven by steam-power, at the rate of 170 revolutions in a minute.

The rug in its box is brought to the required distance above the edge of the box by screwing up the bottom. The box is then placed on a rail, and connected with a tolerably fine endless screw. The machine being in motion, the box is carried by the screw under the knife, and by the rapid circular motion, the knife having a razor-like edge, a very clean cut is effected. As soon as the rug is cut off to the extent of a few inches, it is fastened by hooks to strings which wind over cylinders, and thus raise the rug as regularly as it is cut. This goes on until the entire rug is cut off to the thickness of three-sixteenths of an inch. The other portion in the box is now ready to receive another coating, and the application of another surface, to form a second rug, and so on, until about one thousand rugs are cut from the block prepared as we have described.

MOSS AGATE, or **MOCHA STONE.** A variety of chalcedony enclosing dendritic or moss-like markings of an opaque brownish-yellow colour, which are produced by oxide of manganese or iron. It was the *dendrachates* of the ancients.

MOTHER-OF-PEARL (*Nacre de Perles*, Fr.; *Perlenmutter*, Ger.) is the hard, silvery, brilliant internal layer of several kinds of shells, particularly oysters, which is often variegated with changing purple and azure colours. The large oysters of the Indian seas alone secrete this coat of sufficient thickness to render their shells available to the purposes of manufactures. The genus of shell-fish called *Pentadinæ* furnishes the finest pearls, as well as mother-of-pearl; it is found in greatest perfection round the coasts of Ceylon, near Ormus in the Persian Gulf, at Cape Comorin, and among some of the Australian seas. The brilliant hues of mother-of-pearl do not depend upon the nature of the substance, but upon its structure. The microscopic wrinkles or furrows which run across the surface of every slice act upon the reflected light in such a way as to produce the chromatic effect; for Sir David Brewster has shown that if we take with very fine black wax, or with the fusible alloy of D'Arcet, an impression of mother-of-pearl, it will possess the iridescent appearance. Mother-of-pearl is very delicate to work, but it may be fashioned by saws, files, and drills, with the aid sometimes of a corrosive acid, such as the dilute sulphuric or muriatic; and it is polished by colcothar of vitriol.

MOTHER-WATER is the name of the liquid which remains after all the salts that will regularly crystallise have been extracted, by evaporation and cooling, from any saline solution.

MOULDS, ELASTIC. Being much engaged in taking casts from anatomical preparations, Mr. Douglas Fox, surgeon, Derby, found great difficulty, principally with hard bodies, which, when undercut, or having considerable overlaps, did not admit of the removal of moulds of the ordinary kind, except with injury. These difficulties suggested to him the use of elastic moulds, which, giving way as they were withdrawn from complicated parts would return to their proper shape; and he ultimately succeeded in making such moulds of glue, which not only relieved him from all his difficulties, but were attended with great advantages, in consequence of the small number of pieces into which it was necessary to divide the mould.

The body to be moulded, previously oiled, must be secured one inch above the surface of a board, and then surrounded by a wall of clay, about an inch distant from its sides. The clay must also extend rather higher than the contained body: into this warm melted glue, as thick as possible so that it will run, is to be poured so as to completely cover the body to be moulded: the glue is to remain till cold, when it will have set into an elastic mass, just such as is required.

Having removed the clay, the glue is to be cut into as many pieces as may be necessary for its removal, either by a sharp-pointed knife, or by having placed threads in the requisite situations of the body to be moulded, which may be drawn away when the glue is set, so as to cut it out in any direction.

The portions of the glue-mould having been removed from the original, are to be placed together and bound round by tape.

In some instances it is well to run small wooden pegs through the portions of glue, so as to keep them exactly in their proper positions. If the mould be of considerable size, it is better to let it be bound with moderate tightness upon a board to prevent it bending whilst in use; having done as above described, the plaster-of-Paris, as in common casting, is to be poured into the mould, and left to set.

In many instances wax may also be cast in glue, if it is not poured in whilst too hot; as the wax cools so rapidly when applied to the cold glue, that the sharpness of the impression is not injured.

Glue has been described as succeeding well where the elastic mould is alone applicable; but many modifications are admissible. When the moulds are not used soon after being made, treacle should be previously mixed with the glue (as employed by printers), to prevent it becoming hard.

The description thus given is with reference to moulding those bodies which cannot be so done by any other than an elastic mould; but glue moulds will be found greatly to facilitate casting in many departments, as a mould may be frequently taken by this method in two or three pieces, which would, on any other principle, require many.

MOUNTAIN BLUE. Blue copper ore. See Copper.

MOUNTAIN CORK. A form of asbestus. See Asbestus.

MOUNTAIN GREEN. Malachite, or green carbonate of copper. See Copper.

MOUNTAIN LEATHER. Asbestus is so called when it is so interlaced that the fibrous structure is not apparent. See Asbestus.

MOUNTAIN LIMESTONE. A term commonly applied to the carboniferous limestone, on account of its masses forming some of our finest mountain scenery. It may be regarded as the boundary rock of nearly all our coal-formations. See Carboniferous Limestone.

MOUNTAIN SOAP (*Savon de montagne*, Fr.; *Bergseife*, Ger.) is a tender mineral, soft to the touch, which assumes a greasy lustre when rubbed, and falls to pieces in water. It consists of silica 44, alumina 26·5, water 20·5, oxide of iron 8, lime 0·5. It occurs in beds, alternating with different sorts of clay, in the Isle of Skye, at Billin in Bohemia, &c. It has been often, but improperly, confounded with steatite.

MUCIC ACID (*Acid mucique*, Fr.; *Schleimsäure*, Ger.) is the same as the saclactic acid of Scheele, and may be obtained by digesting one part of gum arabic, sugar-of-milk, or pectic acid, with twice or thrice their weight of nitric acid. It forms white granular crystals, and has not been applied to any use in the arts.

MUCILAGE is a solution in water of gummy matter of any kind.

MUFFLE is the earthenware case or box, in the assay furnaces, for receiving the cupels, and protecting them from being disturbed by the fuel. See Assay.

MULBERRY OIL. A flavouring essence introduced by Mr. Condy, which consists chiefly of suberic ether. See Suberic Acid.

MULBERRY PAPER. The *Broussonetia papyrifera*; the inner bark of this species is used in China for the preparation of a kind of paper, and in Polynesia for the production of a peculiar cloth.

MULBERRY TREE. The *Morus nigra* is the common mulberry, and *M. alba* the white mulberry. The leaves of both species are used for feeding silkworms.

MULE. A machine for spinning cotton. See Cotton Spinning.

MULHOUSE BLUE. The name given to one of the aniline colours prepared by Gros, Renaud, and Schaeffer, of Mulhouse. It is formed by boiling the solution of rosaniline salt (nitrate is generally used) with a solution of gum-lac and carbonate of sodium. See Aniline.

MUM. A malt liquor made in Brunswick with wheat meal and oat and bean meal.

MUNDIC is the name of iron or arsenical pyrites among Cornish miners.

MUNGO (sometimes also termed *Shoddy*) is the artificial wool formed by tearing to pieces, and completely disintegrating old woollen cloths or garments, or even pieces of new cloth, such as tailor's clippings.

MUNJEET or East Indian madder, the *Rubia Munjista*. See Madder.

MUNJISTINE. An orange colouring-matter contained together with purpurine in munjeet. This colouring-matter has been so thoroughly investigated by Dr. Stenhouse, that it cannot be better described than in his own words. His paper in the 'Proceedings of the Royal Society of London,' vol. xii. p. 633, is entitled 'Preliminary Notice of an Examination of *Rubia Munjista*, the East Indian Madder, or Munjeet of commerce:'

'It is rather remarkable that while few vegetable substances have been so frequently and carefully examined by some of the most eminent chemists as the root of the *Rubia tinctorum* or ordinary madder, the *Rubia Munjista* or munjeet, which is so extensively cultivated in India, and employed as a dye-stuff, has been, comparatively speaking, very much overlooked, never having been subjected, apparently, to anything but a very cursory examination.

'From some incidental notices of munjeet in Persoz and similar writers, and a few experiments which I made some years ago, I was led to suspect that the colouring-matters in munjeet, though similar, are by no means identical with those of ordinary madder, and that probably the alizarine or purpurine of madder would be found to be replaced by some corresponding colouring principle. This hypothesis I have found to be essentially correct, for the colouring-matter of munjeet, instead of consisting of a mixture of alizarine and purpurine, contains no alizarine at all, but purpurine and a beautiful orange colouring-matter, crystallising in golden scales, to which I purpose giving the name of *munjistine.* Munjistine exists in munjeet in considerable quantity, and can therefore be easily obtained.

'The colouring-matter of munjeet may be extracted in various ways: that which I have found most suitable is as follows: each pound of munjeet in fine powder is boiled for four or five hours with 2 pounds of sulphate of alumina and about 16 pounds of water. The whole of the colouring-matter is not extracted by a single treatment with sulphate of alumina; the operation must be repeated, therefore, two or three times. The red liquid thus obtained is strained through cloth filters while still very hot, and the clear liquid acidulated with hydrochloric acid. It soon begins to deposit a bright red precipitate, the quantity of which increases on standing, which it should be allowed to do for about twelve hours. This precipitate is collected on cloth filters and washed with cold water till the greater portion of the acid is removed. It is then dried, reduced to a fine powder, and digested in a suitable extracting apparatus with boiling bisulphide of carbon, which dissolves out the crystallisable colouring principles of the munjeet, and leaves a considerable quantity of dark-coloured resinous matter. The excess of the bisulphide of carbon having been removed by distillation, the bright red extract, consisting chiefly of a mixture of munjistine and purpurine, is treated repeatedly with moderate quantities of boiling water and filtered. The munjistine dissolves, forming a clear yellow liquid, while almost the whole of the purpurine remains on the filter. When the solution is acidulated with hydrochloric or sulphuric acid, the munjistine precipitates in large yellow flocks. These are collected on a filter and washed slightly with cold water. The precipitate is then dried by pressure and dissolved in boiling spirits of wine, slightly acidulated with hydrochloric acid to remove any adhering alumina. As the munjistine does not subside from cold alcoholic solutions, even when they are largely diluted with water, about three-fourths of the spirit are drawn off by distillation, when the munjistine is deposited in large yellow scales. By two or three crystallisations out of spirit in the way just described, the munjustine is rendered perfectly pure.

'I have likewise succeeded in extracting munjistine directly from munjeet by boiling it with water, filtering the solution, which has a dark brownish colour, and then acidulating with hydrochloric acid. The precipitate which falls is collected on a filter, washed, dried, and treated with boiling spirits of wine, which leaves a large quantity of pectine undissolved.

'The munjistine which dissolves in the alcohol is obtained in a pure state by repeated crystallisations in the way already indicated. The first process which I have described is, however, by far the best. The colouring-matter of munjeet can likewise be extracted with boiling solutions of alum; but I find sulphate of alumina greatly preferable, as the alum by its tendency to crystallise very much impedes the filtration of the liquids. I likewise attempted to employ Professor C. Hopp's process with sulphurous acid, which gives such excellent results with ordinary madder, but I found it wholly inapplicable to munjeet.

'Munjistine, prepared by the processes described, when crystallised out of alcohol, forms golden-yellow plates of great brilliancy. It is but moderately soluble in cold, but dissolves pretty readily in boiling water, forming a bright yellow solution, from which it is deposited in flocks when the liquid cools. Saturated solutions almost gelatinise. It dissolves to some extent in cold, but more readily in boiling, spirit of wine, and is not precipitated by the addition of water. It dissolves in carbonate of soda with a bright red colour. In ammonia it forms a red solution with a slight tinge of brown caustic soda, producing with it a rich crimson colour. Both its aqueous and alcoholic solutions, when boiled with alumina, form beautiful flakes of a bright orange colour, almost the whole of the munjistine being withdrawn from solution. The flakes are soluble in a large excess of caustic soda, with a fine crimson colour. Munjistine dyes cloth mordanted with alumina a bright orange. With iron mordant it yields a brownish-purple colour, and with Turkey-red mordant a pleasing deep orange. These colours are moderately permanent, and bear the application of bran and soap tolerably well. The munjistine sensibly modifies the colours produced by munjeet, giving the reds a shade of scarlet, as has been long observed.

'Commercial nitric acid dissolves munjistine with a yellow colour, but does not appear to decompose it even on boiling. Fuming nitric acid (1·5) dissolves munjistine in the cold, and on application of heat decomposes it, no oxalic acid being produced. It readily dissolved in cold sulphuric acid with a bright orange colour; and the solution may be heated nearly to boiling without blackening or giving off sulphuric acid; it is reprecipitated by water in yellow flocks apparently unaltered. When bromine water is added to a strong aqueous solution of munjistine, a pale-coloured flocculent precipitate is immediately produced; this, when collected on a filter, washed and dissolved in hot spirit, furnishes minute tufts of crystals, evidently a substitution-product. I may remark in passing, that when alizarine is treated with bromine water in a similar way, it also forms a substitution-product, crystallising in needles.

'Munjistine, in some of its properties, bears considerable resemblance to Runge's madder orange, the *rubiacine* of Dr. Schunck; it is, however, essentially different from rubiacine in several of its properties, such as its solubility in water and alcohol, &c., and in the amount of its carbon—rubiacine, according to Dr. Schunck's analysis, containing 67·01 per cent. of that element, while munjistine contains only 64. The spectra afforded by solution of the two substances, as may be seen from the following extract from a letter received from Professor Stokes, are decidedly different:—

'"The two substances are perfectly distinguished by the very different colour of their solution in carbonate of soda, when a small quantity only of substance is used. The solution of munjistine is red, inclining to pinkish orange, that of rubiacine a claret-red. The tints are totally different, and indicate a different mode of absorption. Both present a single minimum in the spectrum, but while that of rubiacine extends from about D to F, that of munjistine extends from a good way beyond D to some good way beyond F. The beginning and end of the band in each case are not very definite, and vary of course with the strength of the solution; there can be no doubt of the radical difference in the position of the band of absorption. In this way it is easy to convince oneself that the difference of the colour is not to be explained by the possible admixture of some small impurity present in one or other of the specimens. With caustic potash, munjistine gives as nearly as possible the same colour as rubiacine, agreeing with the colour of rubiacine in carbonate of soda. There appears to be a slight difference in the spectrum of the munjistine and rubiacine solutions, but not enough to rely on; so that the substances are not to be distinguished by their solutions in *caustic* alkalis.

'A second perfectly valid distinction is, however, afforded by the different colour of the fluorescent light of the ethereal solutions. The solid substances themselves and their ethereal solutions are fluorescent to a considerable degree; but the tint of the fluorescent light of the ethereal solution of rubiacine is orange-yellow, while that of the ethereal solution of munjistine is yellow inclined to green. The examination in a pure spectrum shows that the difference is not due to the admixture of a small impurity, itself yielding a fluorescent solution; but the tints may be readily contrasted by daylight, almost without apparatus, by the method I have described in a paper, "On the Existence of a Second Crystallisable fluorescent Substance in the Bark of the Horse-chestnut" ("Quart. Journal Chem. Soc. vol. ii., p. 20). I consider either of the two points of difference I have mentioned sufficient by itself to establish the non-identity of munjistine and rubiacine."

'The purpurine which I succeeded in extracting from munjeet and in purifying from munjistine in the way already described, formed beautiful dark crimson needles having all the usual properties of that substance. When examined by Professor Stokes, they gave the very characteristic spectra of purpurine.

'*Tinctorial Power of Munjistine and Munjeet.*—Professor Runge stated in 1835 that munjeet contained twice as much available colouring-matter as the best Avignon madder. This result was so unexpected, that the Prussian Society for the Encouragement of Manufactures, to whom Professor Runge's memoir was originally addressed, referred the matter to three eminent German dyers, Messrs. Dannenberger, Böhn, and Nobiling. These gentlemen reported, as the result of numerous and carefully conducted experiments, that so far from munjeet being richer in colouring-matter than ordinary madder, it contained considerably less. This conclusion has been confirmed by the experience of my friend Mr. John Thorn, of Birkacre near Chorley, one of the most skilful of the Lancashire printers.

'From a numerous series of experiments I have just completed, I find that the garancine from munjeet has about half the tinctoral power of the garancine made from the best madder, viz. Naples roots. These, however, yield only about 30 to 33 per cent. of garancine, while munjeet, according to my friend Mr. Higgin of Manchester, yields from 52 to 55 per cent. Taking the present prices, therefore, of madder at 36 shillings per cwt. and munjeet at 30 shillings, it will be found that there will be scarcely any pecuniary advantage in using munjeet for ordinary madder-dyeing. The colours from munjeet are certainly brighter, but not so durable as those from madder, owing to the substitution of purpurine for alizarine. There is, however, great reason to believe that some of the Turkey-red dyers are employing garancine from munjeet to a considerable extent. When this is the case they evidently sacrifice fastness to brilliancy of colour. By treating such a garancine with boiling water, and precipitating by an acid in the way already described, its sophistication with munjeet may very readily be detected. The actual amount of colouring-matter in munjeet and the best madder is very nearly the same; but the inferiority of munjeet as a dye-stuff results from its containing only the comparatively feeble colouring-matters, purpurine and munjistine, a small portion of the latter being useful, whilst the presence of munjistine in large quantities appears to be positively injurious. So much is this the case that when the greater part of the munjistine is removed from munjeet-garancine by boiling water, it yields much richer shades with alumina mordants than before.'

MUNTZ'S METAL. A brass composed generally of 40 parts of zinc to 60 of copper. These proportions may be somewhat varied, but the above are commonly regarded as the most favourable for rolling into sheets. The metal being properly melted is cast into ingots, heated to a red heat, and rolled into sheathing, and worked into ship's bolts at that heat. It will not work well at a lower heat. This metal was originally patented by the late G. F. Muntz, of Birmingham, in 1832. It has to a large extent superseded the use of copper sheathing, as being cheaper, and at the same time keeping the ships' bottoms cleaner.

MUREX. This genus, belonging to the Mollusca, contains many beautiful shells, from which the Tyrian purple of the ancients was probably obtained.

MUREXANE. The purpuric acid of Prout.

MUREXIDE. Syn. *Purpurate of Ammonia.* $C^{16}H^{8}N^{6}O^{12}$ ($\mathbf{C^{8}H^{8}N^{6}O^{6}}$). Murexide is one of those substances which, although investigated by many chemists of great reputation, has long been regarded as of uncertain constitution. This is the more remarkable from the fact that, owing to its extreme beauty it has always attracted a large amount of attention. It is invariably formed when the product of the action of moderately strong nitric acid on uric acid is treated with ammonia. This process, however, is rather valuable as a test of the presence of uric acid than as a method of procuring murexide. Dr. Gregory who has given much attention to the best methods of preparing the substance in question, has published the following formula for working on the small scale:—'Four grains of alloxantine and seven grains of hydrated alloxan are dissolved together in half an ounce by measure of water by boiling, and the hot solution is added to one-sixth of an ounce by measure of a saturated or nearly saturated solution of carbonate of ammonia, the latter being cold. This mixture has exactly the proper temperature for the formation of murexide; and it does not, owing to its small bulk, remain too long hot. It instantly becomes intensely purple, while carbonic acid is expelled; and as soon as it begins to cool the beautiful green and metallic-looking crystals of murexide begin to appear. As soon as the liquid is cold, these may be collected, washed with a little cold water, and dried on filtering-paper.'

The analyses of murexide are rather discordant, the carbon in all of them being in excess. This arises from the very large amount of nitrogen present, a certain portion becoming acidified passes into the potash apparatus, causing an undue increase in its weight. The following are the principal analyses:—

	Liebig and Wöhler	Liebig	Fritzsche	Beilstein	Calculation
Carbon . .	34·08	34·40	34·93	34·18	C^{16} 33·80
Nitrogen . .	32·90	31·80	30·80	30·35	N^{6} 29·58
Hydrogen . .	3·00	3·00	2·83	3·11	H^{8} 2·82
Oxygen . .	30·02	30·80	31·44	32·36	O^{12} 33·80

There appears no doubt whatever that the formula $C^{16}N^{6}H^{8}O^{12}$ represents its true composition. Murexide is formed when uramile, murexane, or dialuramide, as it is sometimes called, is boiled with peroxide of mercury. Dr. Gregory regarded murexane as a separate substance, and as identical with purpuric acid; he also considered $C^{6}N^{2}H^{4}O^{5}$ as its probable formula. This appears from more recent researches to be incorrect, as murexane is doubtless the same substance as uramile, while purpuric acid, which is bibasic, is represented by the formula $C^{16}H^{5}N^{5}O^{12}$. The formulæ above given for murexide and uramile renders the reaction of peroxide of mercury with the latter easily intelligible; it is, in fact, a very simple case of oxidation, thus:—

$$\underbrace{2C^{8}N^{3}H^{5}O^{6}}_{\text{Uramile.}} + 2O = \underbrace{C^{16}N^{6}H^{8}O^{12}}_{\text{Murexide.}} + 2HO \quad (\mathbf{C^{8}N^{6}H^{10}O^{6} + O = C^{8}N^{6}H^{8}O^{6} + H^{2}O}).$$

The limits of this work preclude any further notice of the scientific relations of murexide, but it is necessary that we should consider it in its character as a dye-stuff. It has been found that murexide forms a series of beautiful compounds with certain metallic oxides, more especially lead and mercury, and these compounds have been employed to a very large extent in the dyeing, and more especially printing, of cotton goods. It is plain that if uric acid were only obtainable from the urine of serpents or the sediments from the urine of mammalia, it could never be made use of in the arts. It happens, however, that the solid urine of birds contains it in large quantity, and since we have become acquainted with the vast deposits of guano existing in various parts of the globe, the manufacture of murexide has been carried out on a scale which would, a few years ago, have appeared impossible. We must, in order to be clear, divide the process into two parts: one being the preparation of uric acid from guano, the other the conversion of the acid into murexide.

Preparation of Uric Acid from Guano.—In order to get rid, as much as possible, of the impurities contained in the guano, it is in the first place to be treated with muriatic acid, which will remove carbonate and oxalate of ammonia, carbonate and phosphate of lime, and ammonio-magnesian phosphate. The uric acid will also be liberated from the substances with which it may be in combination. The operation may be performed in a leaden vessel, heated with a leaden coil, through which steam passes. It is essential to success that the guano be added slowly, otherwise the violent effervescence, which is caused by the decomposition of the carbonates by the acid, would cause the liquid to escape from the vessel. The mixture of guano and muriatic acid is then to be heated for an hour, after which it may be run off into tubs to be washed with water by decantation. The first washings contain a large quantity of ammonia in the state of sal-ammoniac; it should be worked up in some way, in order to prevent the loss of so valuable a salt. As soon as the residue of the guano is sufficiently washed it may be transferred to cloth filters and allowed to drain. The residue from the action of muriatic acid upon 200 lbs. of guano can now be treated by Braun's process for the extraction of the uric acid, It is to be placed in a copper boiler of sufficient capacity, and boiled for an hour with 8 lbs. of caustic soda and 120 gallons of water. It must be constantly stirred. Two or three pounds of quicklime are now to be slaked, enough water is then to be added to make the whole into a thin paste, which is to be poured into the mixture of caustic soda and guano residue. After a quarter of an hour's boiling the fire is to be removed, and the whole allowed to repose until clear. The bright liquid having been syphoned off from the residue, the latter is to be treated with 120 gallons more water and 6 lbs. of soda; 2 lbs. of slaked lime are also to be added in the same manner as in the first operation. The lime is for the purpose of removing extractive matter, and it has been found that it does not do to use it in any other manner than that described. If the soda and lime be allowed to react upon the guano residue at the same time, urate of lime is formed, which, owing to its comparative insolubility, causes much trouble in the subsequent operations.

The two alkaline fluids containing the urate of soda are to be precipitated while warm by a moderate excess of hydrochloric acid. The precipitated uric acid is then to be washed with water and dried.

Conversion of Uric Acid into Murexide by Braun's Process.—In the first place a very large bath of cold water must be provided, having a number of earthenware basins floating upon it. Into each of these basins 2⅛th lbs. of nitric acid are to be poured, the strength of the acid being 36° Beaumé. One pound and three quarters of the uric acid, prepared as above, is now to be added by very small quantities at a time. If the temperature rises above 90° F. the whole is to be allowed to cool before adding any more uric acid. If the water in the bath be so cold that the temperature falls so low as to stop the reaction, it may be set up again by adding warm water to the bath, or, more conveniently, by sending some steam into it for a short time. At first the uric acid need only be added to the nitric acid by sprinkling it on the surface; towards the end of the operation, when the nitric acid has become enfeebled, it is necessary to stir it in. The quantity of mixture contained in two basins is now to be placed in an enamelled iron pot on a sand-bath. As the heat increases the fluid will boil up in the pot, and to prevent loss the vessel must be removed from the fire for a short time. The heating is to be repeated in this manner until the temperature rises to 248° F., and, after removing the pot to the coolest part of the sand-bath, half a pound of liquid ammonia is to be stirred in quickly. In a few minutes the whole is converted into what is called in commerce by the name of *Murexide en pâte.* To convert this into the purer product known as *Murexide en poudre*, it is to be repeatedly stirred up with water and filtered, to remove the saline and extractive matters.

In dyeing cotton by means of murexide, it is necessary to use lead and mercury as mordants. Lauth's process consists in fixing oxide of lead upon the fibre by first immersing it in a bath of acetate of lead, and then in ammonia, or by a bath of oxide of lead and lime. The dye is then mixed with pernitrate or perchloride of mercury and a little acetate of soda, and the cotton goods are worked in it for a sufficient time.

For printing, the murexide is mixed with thickened nitrate of lead, and the cloth after printing is dried and subsequently passed through a bath, containing 100 litres of water, 1 kilogramme of corrosive sublimate, and 1 kilogramme of acetate of soda.

In Sagar and Schultz's patent process they pad the cotton goods in a solution of murexide with 6 pounds of nitrate of lead in 8 gallons of water, to which when cold 6 ounces of corrosive sublimate, dissolved in 2 gallons of water, are added. The goods are dried after dyeing in the above solution, and the colour is fixed by again padding in a solution of wheaten starch, gum, gum-substitute, or any similar substance.

Silk may easily be dyed in a bath of murexide mixed with corrosive sublimate. Wool, after being well washed and rinsed, is to be dyed in a strong bath of murexide, and then dried. It is after this to be treated, at a temperature of 104° to 122° F., with a bath containing 60 grammes of corrosive sublimate, 75 grammes of acetate of soda, and 10 litres of water.—C. G. W.

Murexide has now so completely established its place in the arts, that the following notice of it by Dr. Hofmann in his Report on the Chemical Section of the Exhibition of 1862, forms a very appropriate addendum to Mr. Greville Williams' notice.

Historical Notice.—Since the year 1851 there has appeared on the chemical horizon a rare and beautiful substance, formerly looked upon as a laboratory curiosity, a product to be admired for its brilliant metallic lustre, and for the elegance of its delicate crystals, but not otherwise important. In consequence, however, of the application it found in the dyeing and printing of fabrics, it suddenly sprang into great request, and was prepared in extremely large quantities. This substance is *murexide*, first noticed by Prout, but obtained in the state of purity, analysed, and described by MM. Liebig and Wöhler, in the admirable paper on Uric Acid and its derivatives. It was destined, however, to have but a brief celebrity. After having shone for some time with great lustre, it was suddenly eclipsed by even more resplendent rivals—the gorgeous crimsons, purples, and violets derived from aniline and its homologues. Nevertheless, murexide deserves, for more than one reason, our serious attention; indeed, it would be difficult to mention a substance whose history is more instructive. Certainly the resources of modern chemistry were never more admirably illustrated than in the promptness with which the sudden demand for murexide was met; and an operation, delicate and complex, even as a laboratory process, made available on an industrial scale. Those who had only seen murexide adorning as a rarity the shelves of a museum, might well be astonished when they found it by hundredweights in the market, nearly equalling in purity the laboratory product itself, and sold at a price almost incredibly low.

The reporter had the good fortune to be a student in Professor Liebig's laboratory at the time, when, together with Professor Wöhler, he carried on those researches upon uric acid which became celebrated for the brilliant light they threw upon the nature and composition of murexide. He has thus had many opportunities of witnessing the difficulties which arose in the preparation of the substance; and he can record, as he shared, the triumph which the whole laboratory felt when a few grammes of it were first obtained in a state of purity.

Murexide has the formula $C^8H^8N^6O^6$, and has been considered by some as purpurate of ammonium. The acid of this salt cannot, however, be isolated. As soon as it is set free by means of a stronger acid, it is immediately decomposed into other products, murexan, alloxan, &c.

Preparation of Murexide.—The preparation of murexide involves two distinct operations, viz.:—1. The extraction and purification of uric acid. 2. The transformation of uric acid into murexide.

Sources of Uric Acid.—Uric acid is found in the excrements of serpents and birds, and in guano, as urate of ammonium. The excrements of serpents contain almost pure uric acid, partly combined with ammonium, partly free. The supply of these materials is, however, too limited to serve for any other than laboratory experiments.

Almost all the uric acid used in the arts is derived from guano. According to the process patented by Mr. Brooman, the guano is extracted by means of hot dilute hydrochloric acid, which dissolves out the carbonates, oxalates, and phosphates of ammonium, calcium, magnesium, &c. The insoluble residue consists of uric acid, mixed with sand, clay, sulphate of calcium, albumen, mucus, &c. It is treated with fresh quantities of hot hydrochloric acid, washed, drained, and dried. It may then be employed directly for the preparation of murexide.

But if a purer uric acid be required, it may be obtained by dissolving the crude acid in a boiling solution of dilute caustic potash, and precipitating the clear solution with an acid. The uric acid is thus obtained almost pure, and may be filtered, washed, and dried.

The uric acid can also be dissolved in rather concentrated sulphuric acid, heated to 60° to 80° C., and then precipitated by the addition of water, filtered, washed, and dried. 100 parts of good guano yield from two and a half to three parts of uric acid.

Transformation of Uric Acid into Murexide.—For this purpose the uric acid is first dissolved in cold nitric acid, which is placed, for this purpose, in earthenware pots of from four to five litres capacity, and has the uric acid gradually added to it in small quantities; each portion being allowed to dissolve entirely before a fresh quantity is introduced.

This operation takes from ten to twelve hours, and yields a dark brown liquid, consisting chiefly of nitrate of urea, alloxan, and alloxantine. These last two substances frequently form a crystalline crust on the surface of the liquid, and their simultaneous presence forms one of the most favourable conditions for the abundant formation of murexide.

The liquid thus obtained is treated in one or other of the two following modes:—

1. When it is desired to obtain purpurate of sodium, it is simply diluted with water, mixed with carbonate of sodium, and heated.

2. When, on the other hand, purpurate of ammonium, or murexide is required, carbonate of ammonium is added.

The liquid thus obtained is evaporated in glazed vessels of considerable size, care being taken not to raise the temperature beyond 80° C., and not to operate upon too much liquid at one time. In proportion as the liquid becomes more concentrated and pasty, ammonia, set free by the decomposition of the nitrate of urea or urea alone, reacts in its nascent condition, upon the alloxan and alloxantine, and forms murexide, which appears on cooling as a brownish-red or violet substance, sometimes of a greenish tint. This constitutes the *purple carmine* of Mr. Brooman.

It is, however, better to employ ammonia, or its carbonate, added in small quantities at a time to the nitric solution, till the acid liquid is neutral or slightly alkaline, which reaction it should permanently retain. This liquid is then heated to about 60° to 77° C., and yields, on cooling, crystals of murexide. The mother-liquid is again heated with small quantities of ammonia and cooled; when a fresh crop of crystals of murexide is obtained.

Crystallised Murexide.—During the last few years the dyers and printers have gradually abandoned the use of pastes of murexide, in order to employ it solely in the form of crystals. The manufacture of the latter has been brought to such perfection that, crystallised in the shape of magnificent needles, exquisitely beautiful and pure, it has come into commerce at very reduced prices.

Statistics of the Manufacture.—We may form an idea of the extent of this manufacture, at a time when it had reached its culminating point, from a statement made by Messrs. Schunck, Angus Smith, and Roscoe, that the weekly yield of murexide of one factory only—that of Mr. Rumney of Manchester—amounted to no less than twelve cwts., a quantity in the production of which, it is asserted, about twelve tons of guano were consumed. The cost of murexide in paste was originally 30*s.* per lb., but it has gradually fallen to half that price.

Isopurpurate of Ammonium.—According to a private communication from M. E. Kopp, the isopurpurate of ammonium of M. Hlasiwetz, a product obtained by the reaction of cyanide of potassium upon picric acid, is not only isomeric but identical with the murexide obtained from uric acid. M. Kopp bases his opinion upon the fact that in dyeing wool and silk with murexide the same processes are requisite, and give the same results, whether the murexide employed be prepared from picric acid or from uric acid. The dyed stuffs thus produced exhibit no greater differences of hue than may be observed in fabrics dyed by means of aniline reds of different preparations. The manufacture of murexide by means of picric acid and cyanide of potassium is extremely simple. To a hot saturated solution of the cyanide is added a solution of picric acid (one part dissolved in seven or eight parts of boiling water), and the mixture allowed to boil for some time. On cooling it deposits a crystalline mass consisting chiefly of impure purpurate of potassium. By filtering and squeezing through linen, redissolving the crystalline mass in hot water, and adding carbonate of potassium to the filtrate, the salt is reprecipitated: purpurate of potassium is thus obtained, this salt being but slightly soluble in the alkaline liquid. This precipitate is filtered off, pressed and redissolved in hot water; sal-ammoniac is then added, and on cooling, beautiful crystals of murexide are obtained.

Murexide Dyeing and Printing.—The first conception of the industrial application of murexide appears to belong to Dr. Saac, formerly of Wesserling, Haut Rhin, now of Barcelona; the processes for dyeing wool and silk by murexide is due to M. Depouilly; the methods for printing with this material upon cotton were devised by M. Ch. Lauth, who employs as mordants chiefly the salts of mercury, lead, and zinc.

In order to dye silk purple, separate aqueous solutions of murexide and of corrosive sublimate are prepared, containing respectively about five per cent. of colouring matter and of salt. The solution of murexide is mixed in the cold with a certain quantity of the sublimate, and the mixture is acidulated with nitric acid. In this cold bath the silk is agitated until the desired shade of colour has been produced. Subsequent immersion in a sublimate bath containing three per cent. of the salt, imparts to the colour its characteristic freshness and brilliancy; qualities in which it remained without a rival until eclipsed by the still more brilliant and more easily-prepared aniline colours.

In order to dye silk of a brilliant yellow, a salt of zinc is substituted for the salt of mercury, the rest of the process remaining the same. When the fabrics of silk have been dyed, they are passed through water rendered very slightly alkaline by means of a little carbonate of sodium, after which they are washed.

Wool may be dyed with murexide in different ways, either by using the corrosive-sublimate bath first and then applying the murexide; or, by first immersing the fabric in the murexide bath, and afterwards fixing the colour, by passing the web through water and a hot bath of corrosive sublimate to which a little acetate of sodium has been added. Sometimes a certain quantity of nitrate of lead is added to the murexide bath, in order to facilitate the fixing of the colouring-matter.

In order to produce rose-coloured or purple tints by murexide upon cotton, nitrate of lead and murexide are dissolved together in water.

The printed cloth is first suspended in a damp room, then introduced into a room pervaded by a slight ammoniacal atmosphere, which assists in fixing the purpurate of lead; and lastly, passed through a corrosive-sublimate bath, containing one and a half per cent. of salt, to fix the colour firmly on the fabric. This process may be conducted in various ways, but must always be based upon the employment of nitrate of lead and corrosive sublimate.

The murexide colours are very fresh and brilliant, and may be exposed to the light without fading. They are, however, excessively sensitive to the action of sulphurous acid, which tarnishes and discolours them with extreme rapidity. This drawback becomes very serious in places where the use of gas has become general; since in the combustion of even well-purified coal-gas there is always enough sulphurous acid generated to act upon fabrics dyed with murexide.

Although the manufacture of murexide has dwindled to a mere shadow of what it was a few years since, its early career will always be remembered as one of the most interesting and instructive episodes in the chemical history of colouring-matters.

MURIATES were, till the great chemical era of Sir H. Davy's researches upon chlorine, considered to be compounds of an undecompounded acid, the muriatic, with the different bases; but he proved them to be in reality compounds of chlorine with the metals. They are all, however, still known in commerce by their former appellation. The only muriates much used in the manufactures are *muriate of ammonia*, or SAL-AMMONIAC; and *muriate of tin*, for which see CALICO-PRINTING and TIN.

MURIATIC ACID. See HYDROCHLORIC ACID.

MUSACEÆ. The Plantain family. See BANANA.

MUSCADEL WINE. A rich wine of Languedoc. See WINE.

MUSCOVADA. The unrefined brown sugar of commerce. See SUGAR.

MUSCOVITE GLASS. Mica is sometimes so called. See MICA.

MUSK (*Musc*, Fr.; *Moschus*, Ger.) is a peculiar aromatic substance found in a sac between the navel and the parts of generation of a small male quadruped of the deer kind, called by Linnæus *Moschus moschiferus*, which inhabits Tonquin and Thibet. The colour of musk is blackish-brown; it is lumpy or granular, somewhat like dried blood, with which substance, indeed, it is often adulterated. The intensity of its smell is almost the only criterion of its genuineness. When thoroughly dried it becomes nearly scentless; but it recovers its odour when slightly moistened with water of ammonia. The Tonquin musk is most esteemed. It comes to us in small bags covered with a reddish-brown hair; the bag of the Thibet musk is covered with a silver-grey hair.

The musk deer, from the male of which animal species the bag containing this valuable drug is obtained, is a native of the mountainous Kirgesian and Langorian steppes of the Altaï, on the river Irtish, extending eastwards as far as the river Yenesei and Lake Baikal; and generally of the mountains of Eastern Asia, between 30° and 60° of N. lat. There are three kinds of musk known in the London market, which is in truth the great centre of the musk trade. The *Cabardieu*, or *Russian musk*, which is rarely, if ever, adulterated; from its poor fragrance, however, it does not fetch more than 8*s.* an ounce in the pod. The *Assam musk* is next in quality; it is very strong, but has a rank smell; the pods are very large and irregular in shape, their average value is about 20*s.* an ounce. The *Tonquin* or *Chinese musk* yields the kind mostly prized by the perfumer; it is more adulterated than either of the former named, but nevertheless realises at public auction an average of 30*s.* an ounce in the pod.

MUSLIN is a fine cotton fabric, which is worn either white, dyed, or printed.

To render it and other fabrics non-inflammable. This very important inquiry was committed by Professor Graham, at the desire of Her Majesty, to the care of Dr. Oppenheim and Mr. Frederick Versmann, from whose report the following important conclusions have been abstracted. After naming many salts found to be useless or nearly so, they proceed:—'With regard to sulphate of ammonia, the cheapest salt of ammonia, a solution containing 7 per cent. of the crystals, or 6·2 per cent. of anhydrous salt, is a perfect anti-flammable. In 1839, the Bavarian Embassy at Paris caused M. Chevalier to make experiments before them with a mixture of borax and sulphate of ammonia, as recommended by Chevalier, in preference to the sulphate alone. He thought the sulphate would lose part of its ammonia, and thereby give rise to the action of sulphuric acid upon the fabric. The authors say that they now have kept for six months whole pieces of muslin prepared in various ways with this salt, some having been even ironed; but cannot find that the texture was in the least degree weakened. Chevalier's mixture, on the contrary, became injurious to the fabric, not only at temperatures above 212°, but even at summer heat; and this can easily be explained, because he did not actually apply sulphate of ammonia and borax, but biborate of ammonia and sulphate of soda.'

Another drawback of Chevalier's mixture is the roughness which it gives to the fabric, and which could only be overcome by calendering the pieces, while sulphate of ammonia by itself has not this effect. The use of this salt must therefore be strongly recommended. Of all the salts experimented upon, only four appear to be applicable for light fabrics. These salts are—1. Phosphate of ammonia. 2. The mixture of phosphate of ammonia and chloride of ammonium. 3. Sulphate of ammonia. 4. Tungstate of soda.

The sulphate of ammonia is by far the cheapest and the most efficacious salt, and it was therefore tried on a large scale. Whole pieces of muslin (eight to sixteen yards long) were finished, and then dipped into a solution containing 10 per cent. of the salt, and dried in the hydro-extractor. This was done with printed muslins, as well as with white ones, and none of the colour gave way, with the sole exception of madder purple, which became pale. But even this change might be avoided, if care be taken not to expose the piece while wet to a higher than ordinary temperature. Most of these experiments were made at the works of Mr. Crum and of Mr. Cochran. The pieces had a good finish, and some of them were afterwards submitted to Her Majesty for inspection, who was pleased to express her satisfaction.

Table showing the smallest percentage of Salts required in Solution, for rendering Muslin Non-Inflammable ; A, *of Crystallised ;* B, *of Anhydrous Salts. Twelve square inches of the Muslin employed weighed* 33·4 *grains.*

Name of Salts	A	B	Remarks
Caustic soda	8	6·2	Injurious to the fabrics.
Carbonate of soda	27	10	
Carbonate of potash	12·6	10	
Bicarbonate of soda	6	5·4	Not sufficiently efficacious; too volatile.
Borax	25	13·2	Destroys the fabrics above 212° Fahr.
Silicate of soda	...	15·5	Injures the appearance of the fabrics.
Phosphate of soda	80	32	Not sufficiently efficacious.
Sulphate of soda	...	...	A concentrated 72 p. c. solution is insufficient.
Bisulphate of soda	20	18·5	Destroys the fabrics.
Sulphite of soda	25	10·3	
Tungstate of soda	20	16	*Recommended on account of its being the only salt not interfering with the ironing of the fabrics.*
Stannate of soda	20	15·9	Injurious.
Chloride of sodium	...	...	Concentrated solutions are insufficient.
Chloride of potassium	...	...	
Cyanide of potassium	...	10	Poisonous.
Sesquicarbonate of ammonia	...	...	Not available.
Oxalate of ammonia	...	...	
Biborate of ammonia	5	3·6	Destroys the fabrics above 212°.
Phosphate of ammonia	...	10	Efficient but expensive.
Phosp. of ammonia and soda	15	9·8	Expensive and scarcely sufficiently efficacious.
Sulphate of ammonia	7	6·2	*Very efficient, and recommended on account of its low price.*
Sulphite of ammonia	10	9	Deliquescent.
Chloride of ammonium	...	25	Not sufficiently efficacious.
Iodide of ammonium	...	5	Too expensive.
Bromide of ammonium	...	5	
Urea	...	40	
Thouret's mixture	...	12	Efficient, but expensive.
Chloride of barium	...	50	Not sufficiently efficacious.
Chloride of calcium	19·7	10	Deliquescent.
Sulphate of magnesia	50	24·3	Not sufficiently efficacious.
Sulphate of alumina	15	7·7	Destroys the fabric.
Potash-alum	33	18	Not efficacious enough, and destroys the fabric.
Ammonia-alum	25	13	
Sulphate of iron	54	28·8	Not sufficiently efficacious.
Sulphate of copper	18	10	Poisonous.
Sulphate of zinc	20	11·2	
Chloride of zinc	8	5·8	Deliquescent.
Protochloride of tin	5	4·6	Deliquescent.
Protochloride of tin and ammonium	5	4·7	Becomes yellow when exposed to the air.
Pinksalt	...	7	Injures the fabric.

Mr. Crum, who prepared some dresses with phosphate and some with sulphate of ammonia, arrived at the result, that, with the phosphate, the finish is chalky, and not transparent enough, whereas the finish with the sulphate is successful.

During the space of six months none of the fabrics prepared with sulphate of ammonia changed either in colour or in texture; it may therefore be considered as an established fact that the sulphate of ammonia may be most advantageously applied in the finishing of muslins and similar highly inflammable fabrics.

The authors felt, however, the necessity of inquiring further into the effect which ironing would have upon fabrics thus prepared; for all the above-mentioned salts, being soluble in water, require to be renewed after the prepared fabrics have been washed.

Now, the sulphate of ammonia does not interfere with the ironing so much as other salts do, because a comparatively small portion is required: but still, the difficulty is unpleasant, and sometimes a prepared piece, after being ironed, showed brown spots like iron-moulds. On covering the iron with plates of zinc or brass, these spots did not appear; but the difficulty still existed, and a white precipitate covering the plate showed evidently that it is the volatile nature of the salt which interferes with the process. An attempt to counteract this action of the salt, by adding wax and similar substances to the starch, remained also without any result.

For all laundry purposes the tungstate of soda only can be recommended. This salt offers only one difficulty, viz., the formation of a bitungstate, of little solubility, which crystallises from the solution. To obtain a constant solution this inconvenience must be surmounted; and it was found that not only phosphoric acid, in very small proportion, keeps the solution in its original state, but that a small percentage of phosphate of soda has the same effect.

The best way of preparing a solution of minimum strength is as follows:—A concentrated neutral solution of tungstate of soda is diluted with water to 28° Twaddle, and then mixed with 3 per cent. of phosphate of soda. This solution was found to keep, and to answer well; it has been introduced into Her Majesty's laundry, where it is constantly being used.

The effects of the soluble salts having been thus compared, a few remarks are necessary respecting the means which may be adopted permanently to fix anti-flammable expedients, so that the substances prepared may be wetted without losing the property of being non-inflammable.

Relying upon the property of alumina as a mordant, we tried the combination of oxide of zinc and alumina, obtained by mixing solutions of oxide of zinc in ammonia and of alumina in caustic soda; but, although this precipitate protects the fibre, it does not adhere to it when washed.

The oxychloride of antimony, obtained by precipitation from an acid solution of chloride of antimony by water mixed only with a little ammonia, is a good anti-flammable, and it withstands the action of water, but not that of soap and soda. It was not found that the solution of this and other salts in muriatic acid injured the texture of the fabric as long as this was dried at an ordinary temperature.

The borate and phosphate of protoxide of tin act effectually, if precipitated in the fibre from concentrated solutions of these salts in muriatic acid by ammonia; they withstand the influence of washing, and give a yellow tinge to the fabrics.

The same remarks apply to arsenate of tin. The stannates of lime and zinc protect the fabric, but do not withstand the action of soap or soda.

The oxides of tin give a favourable result, inasmuch as they really can be permanently fixed; the yellow tinge, however, which they impart to the fabrics will always confine their application to coarse substances, such as canvas, sail-cloth, or ropes.

The canvas thus prepared must be dried and then washed, to remove the excess of precipitate. Salt-water does not remove the tin from the canvas.

A piece about 40 yards in length has been prepared by order of the Storekeeper-General of the Royal Navy; but it was found to have lost in strength, and increased in weight too much to allow of its application.

These experiments, however, being the first successful attempts permanently to fix some anti-flammable agents, may have some interest, although they leave but little hope that the result of fixing anti-flammable expedients will ever be obtained without injuring the fabrics.

By determining the comparative value, and ascertaining the difficulties which have prevented, till now, the general use of protecting agents, the authors were led to exclude a number of salts hitherto proposed, and to advocate the adoption of sulphate of ammonia, and of tungstate of soda, in manufactories of light fabrics, and in laundries.

They hope, therefore, that the general introduction of these salts will soon greatly reduce danger and loss of life through fire.

MUSSEL-BAND. Thin shelly bands occurring in the coal-measures are called by the miners mussel-band, or mussel-bind.

MUST is the sweet juice of the grape.

MUSTA PAAT. *Hibiscus cannabinus.* A vegetable fibre, much used in Asia. See FIBRES.

MUSTARD. (*Moutarde*, Fr.; *Senf*, Ger.) The *Sinapis nigra*, or common black mustard, is the plant which yields the well-known seed used as a condiment to food. Flour of mustard is prepared as follows:—The seeds of black and white mustard are first crushed between rollers and then pounded in mortars. The pounded seeds are then sifted. The residue in the sieves is called *dressings*, and what passes through is the *impure flour of mustard*, which by a second sifting yields the pure flour. Common mustard is adulterated with wheat-flour, and coloured with turmeric, being rendered hot by pod-pepper.

Mustard consists of:—

Myronic acid, an inodorous, non-volatile, bitter, non-crystallisable acid.

Myrosine, a substance in many respects analogous to vegetable-albumen.

Sinapisine, white, brilliant, micaceous, volatile crystals.

Oil of Mustard.—Volatile oil of mustard is colourless or pale yellow; it has a penetrating odour, and a most acrid burning taste. It is represented by the formula $C^8H^5NS^2$ ($\mathbf{C^4H^5NS}$).

Fixed Oil of Mustard.—This constitutes 28 per cent. of the seeds. It has a faint odour of mustard, and a mild oily taste.

M. Lenormand gives the following prescription for preparing mustard for the table. This is usually termed *French mustard*:—

With 2 lbs. of very fine flour of mustard, mix ½ an ounce of each of the following fresh plants: parsley, chervil, celery, and taragon; along with a clove of garlic, and 12 salt anchovies, all well minced. The whole is to be triturated with the flour of mustard till the mixture becomes uniform. A little grape-must or sugar is to be added to give the requisite sweetness; then 1 ounce of salt, with sufficient water to form a thinnish paste by rubbing in a mortar. With this paste the mustard-pots being nearly filled, a red-hot poker is thrust down into the contents of each, which removes (it is said) some of the acrimony of the mustard, and evaporates a little water, so as to make room for pouring a little vinegar upon the surface of the paste. Such table-mustard not only keeps perfectly well, but improves with age.

MUSTARD OIL. See OILS.

MUTAGE is a process used in the south of France to arrest the progress of fermentation in the must of the grape. It consists either in diffusing sulphurous acid, from burning sulphur matches, in the cask containing the must, or in adding a little sulphide (not sulphate) of lime to it. The last is the best process. See FERMENTATION.

MUTTON SUET is much used in leather manufactories for tallowing hides, Its composition is: carbon 78·996, hydrogen 11·700, oxygen 9·304.

MYRICINE is a vegetable principle which constitutes from 20 to 30 per cent. of the weight of bees'-wax, being the residuum from the solvent action of alcohol upon that substance. It is a greyish-white solid, which may be vaporised almost without alteration.

MYRRH is a gum-resin, which occurs in tears of different sizes; they are reddish-brown, semi-transparent, brittle, of a shining fracture, appear as if greasy under the pestle; they have a very acrid and bitter taste, and a strong, not disagreeable, smell. Notwithstanding the early knowledge of, and acquaintance with the use of myrrh, we had no accurate account of the tree which yields it until the return of Ehrenberg from his travels with Heinfrich during 1820–25, in various parts of Africa and Asia. He brought with him a specimen of the tree, which had been described and figured by Neesvon Esonbeck under the name of *Balsamodendron myrrha*. The plant is first noticed by Alexander Humboldt in 1826.—*Pereira.*

Myrrh is of three qualities:—The first quality, *Turkey myrrh*, occurs in pieces of irregular form and of various sizes, consisting of tears, usually covered with a fine powder or dust. The second quality, *East India myrrh*, is imported from the East Indies in chests; it consists of distinct tears or grains, which are rounded or irregular, and vary in size from that of a pin's head to a pepper corn. The third quality is also *East India myrrh*, but it occurs in pieces of a dark colour, and whose average size is that of a walnut.

Myrrh flows from the incisions of a tree which grows at Gison, on the borders of Arabia Felix. The tree figured by Humboldt is considered by Lindley as identical with the *Amyris Kataf* of Forskål. It consists of resin and gum in proportions stated by Pelletier at 31 of the former and 66 of the latter; but by Braconnot, at 23 and 77. It is used only in medicine.

N

NACARAT is a term derived from the Spanish word *nacar*, which signifies mother-of-pearl; and is applied to a pale red colour, with an orange cast. The *Nacarat* of Portugal, or *Bezetta*, is a crape or fine linen fabric, dyed fugitively of the above tint, which ladies rub upon their countenances to give them a roseate hue. The Turks of Constantinople manufacture the brightest red crapes of this kind.

NACREOUS. (*Nacre*, Fr.) A term applied to shells and minerals which have a pearly or iridescent lustre.

NAGYAGITE. A native telluride of lead containing gold, silver, and copper.

NAILS, MANUFACTURE OF. (*Clou*, Fr.; *Nagel*, Ger.) The forging of nails was till of late years a handicraft operation, and therefore belonged to a book of trades rather than to a dictionary of arts. But several combinations of machinery have been recently employed, under the protection of patents, for making these useful implements, with little or no aid of the human hand; and these deserve to be noticed, on account both of their ingenuity and importance.

As nails are objects of prodigious consumption in building their block-houses, the citizens of the United States very early turned their mechanical genius to good account in the construction of various machines for making them. So long since as the year 1810, it appears the Americans possessed a machine which performed the cutting and heading at one operation, with such rapidity that it could turn out upwards of 100 nails per minute. 'Twenty years ago,' says the secretary of the State of Massachusetts, 'some men, then unknown, and then in obscurity, began by cutting slices out of old hoops, and, by a common vice griping these pieces, headed them with several strokes of the hammer. By progressive improvements slitting-mills were built, and the shears and the heading tools were perfected; yet much labour and expense were requisite to make nails. In a little time Jacob Perkins, Jonathan Ellis, and a few others, put into execution the thought of cutting and of heading nails by water-power; but, being more intent upon their machinery than upon their pecuniary affairs, they were unable to prosecute the business. At different times other men have spent fortunes in improvements, and it may be said with truth that more than one million of dollars has been expended; but at length these joint efforts are crowned with complete success, and we are now able to manufacture, at about one-third of the expense that wrought nails can be manufactured for, nails which are superior to them for at least three-fourths of the purposes to which nails are applied, and for most of those purposes they are full as good. The machines made use of by Ordiorne, those invented by Jonathan Ellis, and a few others, present very fine specimens of American genius.

'To northern carpenters it is well known that in almost all instances it is unnecessary to bore a hole before driving a cut nail; all that is requisite is, to place the cutting edge of the nail across the grain of the wood; it is also true that cut nails will hold better in the wood. These qualities are, in some rough building works, worth twenty per cent. of the value of the article, which is equal to the whole expense of manufacturing. For sheathing and drawing, cut nails are full as good as wrought nails; only in one respect are the best wrought nails a little superior to cut nails, and that is where it is necessary they should be clenched. The manufacture of cut nails was born in our country, and has advanced, within its bosom, through all the various stages of infancy to manhood; and no doubt we shall soon be able, by receiving proper encouragement, to render them superior to wrought nails in every particular.

'The principal business of rolling and slitting-mills is rolling nail plates; they also serve to make nail rods, hoops, tires, sheet iron and sheet copper. In this State we have not less than twelve.

'These mills could roll and slit 7,000 tons of iron a year; they now, it is presumed, roll and slit each year about 3,500 tons, 2,400 tons of which, probably, are cut up into nails and brads, of such a quality that they are good substitutes for hammered nails, and in fact, have the preference with most people, for the following reasons; viz. on account of the sharp corner and true taper with which cut nails are formed; they may be driven into harder wood without bending or breaking, or hazard of splitting the wood, by which the labour of boring is saved, the nail one way being of the same breadth or thickness from head to point.'

Since the year 1820, numerous patents have been taken out in this country for the manufacture of nails by machinery. A few only of these can be noticed.

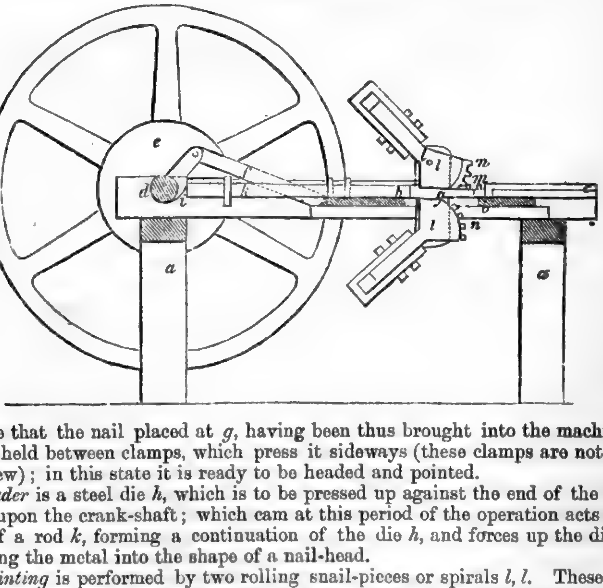
The first nail apparatus to which we shall advert is due to Dr. Church; it was patented by Mr. Thomas Tyndall, of Birmingham, in December 1827. It consists of two parts: the first is a mode of forming nails, and the shafts of screws, by pinching or pressing ignited rods of iron between indented rollers; the second produces the threads on the shafts of the screws previously pressed. The metallic rods, by being passed between a pair of rollers, are rudely shaped, and then cut asunder between a pair of shears; after which they are pointed and headed, or otherwise brought to their finished forms, by the agency of dies placed in a revolving cylinder. The several parts of the mechanism are worked by toothed wheels, cams, and levers. The second part of Dr. Church's invention consists of a mechanism for cutting the threads of screws to any degree of obliquity or form.

Mr. Edward Hancorne, of Skinner Street, London, nail-manufacturer, obtained a patent in October 1828, for a nail-making machine, of which a brief description may give a conception of this kind of manufacture. Its principles are similar to those of Dr. Church's more elaborate apparatus.

The rods or bars having been prepared in the usual way, either by rolling or hammering, or by cutting from sheets or plates of iron, called slitting, are then to be made red-hot, and in that state passed through the following machine, whereby they are at once cut into suitable lengths, pressed into wedge forms for pointing at the one end, and stamped at the other end to produce the head. A longitudinal view of the machine is shown in *fig.* 1544. A strong iron frame-work, of which one side is shown at *a a*, supports the whole of the mechanism. *b* is a table capable of sliding to and fro horizontally. Upon this table are the clamps, which lay hold of the sides of the rod as it advances; as also the shears which cut the rod into nail-lengths.

These clamps or holders consist of a fixed piece and a moveable piece; the latter being brought into action by a lever. The rod or bar of iron shown at *c*, having been made red-hot, is introduced into the machine by sliding it forward upon the table *b*, when the table is in its most advanced position; rotatory motion is then given to the crank-shaft *d*, by means of a band passing round the rigger pulley *e*, which causes the table *b* to be drawn back by the crank-rod *f*; and as the table recedes, the horizontal lever is acted upon, which closes the clamps. By these means the clamps take fast hold of the sides of the heated rod, and draw it forward, when the moveable chap of the shears, also acted upon by a lever, slides laterally, and cuts off the end of the rod held by the clamps: the piece thus separated is destined to form one nail.

1544



Suppose that the nail placed at *g*, having been thus brought into the machine and cut off, is held between clamps, which press it sideways (these clamps are not visible in this view); in this state it is ready to be headed and pointed.

The *header* is a steel die *h*, which is to be pressed up against the end of the nail by a cam, *i*, upon the crank-shaft; which cam at this period of the operation acts against the end of a rod *k*, forming a continuation of the die *h*, and forces up the die, thus compressing the metal into the shape of a nail-head.

The *pointing* is performed by two rolling snail-pieces or spirals *l*, *l*. These pieces are somewhat broader than the breadth of the nail; they turn upon axles in the side frames. As the table *b* advances, the racks *m*, on the edge of this table, take into the toothed segments *n*, *n*, upon the axles of the spirals, and cause them to turn round.

These spirals pinch the nail at first close under its head with very little force; but as they turn round, the longer radius of the spiral comes into operation upon the nail, so as to press its substance very strongly, and squeeze it into a wedge form. Thus the nail is completed, and is immediately discharged from the clamps or holders. The carriage is then moved again by the rotation of the crank-shaft, which brings another portion of the rod *c*, forward, cuts it off, and then forms it into a nail.

Dr. William Church, February 1832, obtained a patent for improvements in machinery for making nails. These consist, first, in apparatus for forming rods, bars, or plates of iron, or other metals; secondly, in apparatus for converting the rods, &c. into nails. The machinery consists of laminating rollers, and compressing dies.

The method of forming the rods from which nails are to be made is very advantageous. It consists in passing the bar or plate iron through pressing rollers, which have indentations upon the peripheries of one or both of them, so as to form the bar or plate into the required shape for the rods, which may be afterwards separated into rods of any desired breadth, by common slitting-rollers.

The principal object of rolling the rods into these wedge forms, is to measure out a quantity of metal duly proportioned to the required thickness or strength of the nail in its several parts; which quantity corresponds to the indentations of the rollers.

Thomas John Fuller patented an improved apparatus for making square-pointed, and also flat-pointed nails. His invention consisted of the application of vertical and horizontal hammers (mounted in his machine) combined for the purpose of tapering and forming the points of the nails; which, being made to act alternately, resemble hand-work, and are therefore not so apt to injure the fibrous texture of the iron, as the rolling machinery is. He finishes the points by rollers.

William Southwood Stocker introduced a machine apparently of American parentage, as it has the same set of features as the old American mechanisms of Perkins, at the Britannia Nail Works, Birmingham, and all the other American machines for pressing metal into the forms of nails, pins, screw-shafts, rivets, &c.; for example, it possesses pressers or hammers for squeezing the rods of metal and forming the shanks, which are all worked by a rotatory action; cutters, for separating the appropriate lengths, and dies for forming the heads by compression, also actuated by revolving cams or cranks.

Mr. Stocker intended, in fact, to effect the same sorts of operations by automatic mechanisms as are usually performed by the hands of a nail-maker with his hammer and anvil; viz. the shaping of a nail from a heated rod of iron, cutting it off at the proper length, and then compressing the end of the metal into the form of the head. His machine may be said to consist of two parts, connected in the same frame; the one for shaping the shank of the nail, the other for cutting it off and heading it. The frame consists of a strong table to bear the machinery. Two pairs of hammers, formed as levers, the one pair made to approach each other by horizontal movements, the other pair by vertical movements, are the implements by which a portion at the end of a red-hot rod of iron is beaten or pressed into the wedge-like shape of the shaft of a nail. This having been done, and the rod being still hot, is withdrawn from the beaters, and placed in the other part of the machine, consisting of a pair of jaws like those of a vice, which pinch the shank of the nail and hold it fast. A cutter upon the side of a wheel now comes round, and, by acting as the moving chap of a pair of shears, cuts the nail off from the rod. The nail shank being still firmly held in the jaws of the vice, with a portion of its end projecting outwards, the heading die is slidden laterally, until it comes opposite to the end of the nail; the dye is then projected forward with great force, for the purpose of what is termed upsetting the metal at the projecting end of the nail, and thereby blocking out the head.

A main shaft, driven by a band and rigger as usual, brings, as it revolves, a cam into operation upon a lever which carries a double inclined plane or wedge in its front or acting part. The wedge being by the rotatory cam projected forwards between the tails of one of the pairs of hammers, causes the faces of these hammers to approach each other, and to beat or press the red-hot iron introduced between them, so as to flatten it upon two opposite sides. The rotatory cam passing round, the wedge-lever is relieved, when springs instantly throw back the hammers; another cam and wedge-lever now bring the second pair of hammers to act upon the other two sides of the nail in a similar way. This is repeated several times, until the end of the red-hot iron rod, gradually advanced by the hands of the workmen, has assumed the desired form, that is, has received the bevel and point of the intended nail.

The rod is then withdrawn from between the hammers, and in its heated state is introduced between the jaws of the holders, for cutting off and finishing the nail. A bevel pinion upon the end of the main shaft takes into and drives a wheel upon a transverse-shaft, which carries a cam that works the lever of the holding-jaws. The end of the rod being so held in the jaws or vice, a cutter at the side of a wheel upon the transverse-shaft separates, as it revolves, the nail from the end of the rod, leaving the nail firmly held by the jaws. By means of a cam, the heading-die is now slidden laterally opposite to the end of the nail in the holding-jaws, and, by another cam upon the main-shaft, the die is forced forward, which compresses the end of the nail, and spreads out the nail into the form of a head. As the main-shaft continues to revolve, the cams pass away, and allow the spring to throw the jaws of the vice open, when the nails fall out; but, to guard against the chance of a nail sticking in the jaws, a picker is provided, which pushes the nail out as soon as it is finished.

In order to produce round shafts, as for screw blanks, bolts, or rivets, the faces of the hammers and the dies for heading must be made with suitable concavities.

NANKIN is a peculiarly coloured cotton cloth, originally manufactured in the above-named ancient capital of China from a native cotton of a brown-yellow hue. Nankin cloth has been long imitated in perfection by our own manufacturers; and is now exported in considerable quantities from England to Canton. The following is the process for dyeing calico a nankin colour:—

2. Take 300 lbs. of cotton-yarn in hanks, being the quantity which four workmen can dye in a day. The yarn for the warp may be about No. 27's, and that for the weft 23's or 24's.

2. For *aluming* the quantity, take 10 lbs. of saturated alum free from iron (see MORDANT); divide this into two portions; dissolve the first by itself in hot water, so as to form a solution of specific gravity 1° Beaumé. The second portion is to be reserved for the galling-bath.

3. *Galling* is given with about 80 lbs. of oak-bark finely ground. This bark may serve for two quantities, if it be applied a little longer a second time.

4. Take 30 lbs. of fresh slaked quicklime, and form with it a large bath of lime-water.

5. *Nitro-muriate of tin.*—For the last bath 10 or 12 lbs. of solution of tin are used, which is prepared as follows:—

Take 10 lbs. of strong nitric acid, and dilute with pure water till its specific gravity be 26° Beaumé. Dissolve in it 4,633 grains (10½ ounces avoird.) of sal-ammoniac and 3 ounces of nitre. Into this solvent, contained in a bottle set in cold water, introduce successively, in very small portions, 28 ounces of grain-tin granulated. This solution, when made, must be kept in a well-stoppered bottle.

Three coppers are required, one round, about 5 feet in diameter, and 32 inches deep, for scouring the cotton; two rectangular coppers, tinned inside, each 5 feet long and 20 inches deep. Two boxes or cisterns of white wood are to be provided, the one for the lime-water bath, and the other for the solution of tin, each about 7 feet long, 32 inches wide, and 14 inches deep; they are set upon a platform 28 inches high. In the middle, between these two chests, a plank is fixed, mounted with twenty-two pegs for wringing the hanks upon as they are taken out of the bath.

6. *Aluming.*—After the cotton-yarn has been scoured with water in the round copper, by being boiled in successive portions of 100 lbs., it must be winced in one of the square tinned coppers, containing 2 lbs. of alum dissolved in 96 gallons of water, at a temperature of 165° Fahr. It is to be then drained over the copper, exposed for some time upon the grass, rinsed in clear water, and wrung.

7. The *galling.*—Having filled four-fifths of the second square copper with water, 40 lbs. of ground oak-bark are to be introduced, tied up in a bag of open canvas, and boiled for two hours. The bag being withdrawn, the cotton-yarn is to be winced through the boiling tan-bath for a quarter of an hour. While the yarn is set to drain above the bath, 28 ounces of alum are to be dissolved in it, and the yarn being once more winced through it for a quarter of an hour, is then taken out, drained, wrung, and exposed to the air. It has now acquired a deep but rather dull yellowish colour, and is ready without washing for the next process. Bablah may be substituted for oak-bark with advantage.

8. The *liming.*—Into the cistern filled with fresh-made lime-water, the hanks of cotton-yarn suspended upon a series of wooden rods, are to be dipped freely three times in rapid succession; then each hank is to be separately moved by hand through the lime-bath, till the desired carmelite shade appear. A weak soda-lye may be used instead of lime-water.

9. The *brightening* is given by passing the above hanks after squeezing, rinsing, and airing them, through a dilute bath of solution of tin. The colour thus produced is said to resemble perfectly the nankin of China.

Another kind of nankin colour is given by oxide of iron, precipitated upon the fibre of the cloth from a solution of the sulphate by a solution of soda. See CALICO-PRINTING.

NAPHTHA. The term 'naphtha' originally included all inflammable fluids produced during the destructive distillation of organic substances, as well as the fluid hydrocarbons which issue from the earth in certain parts of the world. In this way mineral burning-oil, when first introduced, was called Boghead or Bathgate naphtha; but the term was objectionable, as it confounded the safe-burning oil with the explosive spirit which also is applied to different technical uses, and it is now completely in abeyance. The light spirit from shales and cannels are identical, being composed partly of the olefiant, partly of the paraffin series, while earth-naphtha appears to belong to the latter series. Coal, caoutchouc, bones, wood, and peat, during destructive distillation, first give off naphthas, which are distinguished by their lighter specific gravity when compared with the later products from the still. But this is comparative; for, while an ordinary shale-naphtha may have a density of about 0·750, coal-naphtha has commercially a specific gravity of 0·850.

A description of the new methods of refining shale-oils and naphtha is given further on. (See SHALES AND MINERAL OILS.) But the following description by Greville Williams of his early investigations on Boghead-naphtha (as all the light distillates from Torbanehill mineral were at first designated) is classical.

On the Chemical Nature of the Fluid Hydrocarbons constituting Boghead-Naphtha.

If, when preparing paraffin-oil from coal, the crude oil is rectified with water, a clear transparent naphtha is obtained. This fluid, as found in commerce, is by no means of constant quality. By quality we mean the power of distilling between given limits of temperature. Some kinds are of about the same degree of volatility as commercial benzole, while others distil at nearly the same temperatures as common coal-naphtha. The hydrometer is not a safe guide in choosing this naphtha; this arises from the fact that photogens, of very different degrees of volatility, have almost the same densities. The safest plan is to put the fluid into a retort, having a thermometer in the tubulature, and distil the contents almost to dryness. The careful observation of the range of the mercurial column during the operation is the best mode of ascertaining the quality of the fluid.

The more volatile portions which distil over with water are free from solid bodies, and consist of a mixture of fluids belonging to three series of homologous hydrocarbons, namely, the benzole series; the olefiant gas, or C^nH^n series; and the radicals of the alcohols.

As no works on chemistry contain any directions for the proximate separation of complex mixtures of hydrocarbons, the following description of the method adopted by the author of this article for the separation of the substances contained in Boghead-naphtha may be useful.

It is necessary, in the first place, to determine whether each substance is to be obtained in a state of absolute purity, or whether it is merely desired to obtain the various series distinct from each other. In the process given, it will be supposed that the individual hydrocarbons are required in a state of purity, because it is easy for the operator to leave out any part of the method which may be unnecessary under the particular circumstances of the case. The first step is to obtain constant boiling-points, for it must be remembered that if, when any organic fluid is subjected to distillation with a thermometer in the tubulature of the retort or still, the mercury continues to rise as the fluid comes over, it is at once demonstrated that the substance distilling is not homogeneous. In order to obtain the fluids of constant boiling-point, it is essential to subject them to a complete series of fractional distillations. This is an operation involving great labour, so much so that, in investigating Boghead-naphtha, upwards of one thousand distillations were made before tolerably constant boiling-points were secured. In order to perform the operation successfully, two series of bottles are required, one for the series being *distilled*, and the other for the series *distilling*. As many bottles are necessary as there are 10-degree fractions to be obtained. Thus, supposing the fluid, when first distilled, came over between 100° and 200°, and it has been determined to obtain 10-degree fractions, the receiver is to be changed for every 10° that the mercury rises. Thus, 10 bottles will be required for the fractions distilling, and the same number for the fractions being distilled into. The operation will be commenced by putting the original fluid (dried carefully with chloride of calcium or sticks of potash) into a retort capable of holding at least half as much more fluid as the quantity inserted. Through the tubulature passes a pierced cork, supporting a thermometer, the lower end of which should not dip into the fluid. To the neck of the retort is adapted a good condensing arrangement, so placed that the bottles can be placed beneath the exit-pipe. All the bottles having blank-paper labels attached, the distillation is to be commenced. The first signs of distillation are to be watched for, but no fluid is to be separately received as an individual fraction until boiling has commenced. As soon as it is found that the mercury indicates 10° more than the temperature at which the distillation commenced, the bottle is to be changed, and so on at every 10°. When the whole fluid is distilled away, a smaller retort is to be taken, capable of well holding each 10°-fraction, without fear of anything boiling over. Suppose the first fraction of the first distillation came over between 100° and 110°, it is to be placed in the retort, and the distillation carried on as before. But it will, in almost every instance, be found that the boiling-point will have been reduced 30° or 40° by the removal of the fluids of higher boiling-point. Under any circumstances, however, the distillate is to be received in bottles, and labelled with the boiling-point and the number of the rectification. When all the first 10°-degree fraction has distilled away into the second series of bottles, the next is to be operated on, and so on. By this means only two series of bottles are ever being used at once, viz., the series being distilled, and the series being distilled *into*. Many fluids may be obtained of steady boiling-point by 15 or 16 rectifications, involving, in the case of 10 fractions in each series, at least 150 distillations. But most complex organic fluids, such as naphthas, have a much wider range of boiling-point than 100°. Boghead-naphtha, for example, commences at about 289° Fahr., and rises above 500°. But in the second distillation, the first fraction, instead of distilling at 289°, came over at 250°, the depression of boiling-point being nearly 40°. By proceeding in this manner six times, a fraction was obtained boiling at 210°. When a 10°-fraction no longer splits up during distillation, that is to say, when it comes over almost between the same points at which it last distilled, it will be proper to commence the separation of the various substances present in each fraction. Before doing this, it is often advisable to make a few preliminary experiments, with the view of ascertaining the nature of the fluids present. The more volatile portions may be tested for benzole by converting them into aniline in the method given in the article Benzole. The simplest way of detecting the C^nH^n series (homologous with olefiant gas; see Homologous) will be by ascertaining whether the naphtha is capable of decolourising weak bromine-water. Supposing the presence of these to have been demonstrated, the complete separation of the hydrocarbons may be effected as follows:—Four or five ounces of bromine are to be placed in a large flask, capable of being closed with a well-fitting stopper. About eight volumes of water are then added, and the naphtha of the most volatile fraction is to be poured in by very small portions, the contents of the flask being well shaken after each addition.

By this mode of proceeding, the dark colour of the bromine will gradually fade, and finally disappear. In order to insure a complete reaction, it is better at this stage to add a little more bromine, until the colour is permanent after shaking. A little mercury is now to be poured in, and agitated with the fluids in the flask, to remove all excess of bromine. The oily bromine-compound is now to be separated by means of a tap-funnel, from the mercury and water, and digested with chloride of calcium until every trace of water is removed. The dry brominated oil is now to be distilled, when the radical and benzole series of hydrocarbons will distil away, leaving the brominated oil, which may then be distilled into a vessel by itself. The next step will be to separate the radicals from the benzole series. For this purpose long-necked assay-flasks are necessary. Into one of these vessels, of 3 or 4 ounces capacity, 2 drachms of nitric acid should be poured; 1 drachm of the naphtha is then to be added by very small portions, the flask being kept cool by immersion in cold water. It is essential during the whole time to keep the flask in active motion, in order to bring the hydrocarbon and acid into close contact, and also to cool the contents. If this last precaution be neglected, a violent reaction will occur, and cause the loss of the greater portion of the fluid. When the whole of the drachm of acid has been added, and it is found that the temperature no longer rises on removing the flask from the cold water, the product is to be poured into a narrow and conical glass, and allowed to repose until the hydrocarbon, unacted on, rises to the surface in the form of a transparent brilliant green fluid. The fluid below is then to be removed by means of a pipette, furnished at the upper end with a hollow elastic ball of vulcanised caoutchouc. By this means suction with the lips becomes unnecessary, and the vapours of hyponitric acid are prevented from irritating the lungs. The indifferent hydrocarbon—that is, the fluid unacted on by the acid—is as yet by no means pure; it obstinately retains traces of the benzole and C^nH^n series. It is, therefore, to be transferred to a flask furnished with a well-fitting stopper, and treated with nitric acid (specific gravity 1·5) a considerable number of times. This second treatment may, without any danger of any explosive reaction, be made upon one or two ounces of the partially-purified hydrocarbon. When it is found that the separated nitric acid no longer produces milkiness on being thrown into water, it may be assumed that the benzole and C^nH^n class of hydrocarbons are entirely removed. When the treatment with acid has been repeated a sufficient number of times, the fluid is to be placed in a clean flask, and well agitated with a solution of caustic potash, which will remove the nitrous vapours which are the cause of the green colour. The purified hydrocarbon is then to be separated by a tap-funnel from the water, and dried by digestion with sticks of caustic potash. If it be desired to obtain the radical in a state of absolute purity, it must be distilled three or four times over metallic sodium.

The indifferent hydrocarbons obtained by the above process are colourless mobile fluids, having an odour somewhat resembling the flowers of the white thorn. They are very volatile, even at low temperatures, and have an average density of about 0·716. When the fractions with proper boiling-points have been selected, it will be found that they correspond in specific gravity, percentage composition, and vapour-density with the radicals of the alcohols, as will appear by the following Table, where the experimental results obtained by the author of this article in his examination of Boghead-naphtha are compared with the numbers found by other observers with the radicals obtained by treatment of the hydriodic ethers by sodium, and also by the electrolysis of the fatty acids.

Comparative Table of the Physical Properties of the Alcohol Radicals, as obtained from Boghead-Naphtha, with those procured from other sources.

Radicals	Formulæ		Boiling Points, Fahr.				
			Frankland	Kolbe	Wurtz	Brazier and Gosslett	C. G. Williams
Propyle	$C^{12}H^{14}$	$\mathbf{C^6H^7}$	..	..	..	..	154·4°
Butyle	$C^{16}H^{18}$	$\mathbf{C^8H^{18}}$	..	226·4	222·8°	..	246·2
Amyle	$C^{20}H^{22}$	$\mathbf{C^{10}H^{22}}$	311°	..	316·4	..	318·2
Caproyle	$C^{24}H^{26}$	$\mathbf{C^{12}H^{26}}$	..	..	395·6	395·6°	395·6

Radicals	Formulæ		Densities				Vapour-Densities				
			Frankland	Kolbe at 64·4°	Wurtz at 32°	C. G. Williams at 64·4°	Frankland at 51·8°	Kolbe	Wurtz	C. G. Williams	Theory
Propyle	$C^{12}H^{14}$	$\mathbf{C^6H^7}$	..	..	..	0·6745	..	..	..	2·96	2·97
Butyle	$C^{16}H^{18}$	$\mathbf{C^8H^{18}}$	..	0·6940	0·7057	0·6945	..	4·053	4·070	3·88	3·94
Amyle	$C^{20}H^{22}$	$\mathbf{C^{10}H^{22}}$	4·899	..	0·7413	0·7365	0·7704	..	4·956	4·93	4·91
Caproyle	$C^{24}H^{26}$	$\mathbf{C^{12}H^{26}}$	..	..	0·7574	0·7568	..	..	5·983	5·83	5·87

It has been said that the above hydrocarbons distilled away from the bromine-compound in company with others which were removed by treatment with nitric acid. It was subsequently found that the products formed by the action of the acid were nitro-compounds belonging to the benzole series. The bromine compound contains the C^nH^n series of hydrocarbons, the individual members being determined by the boiling-point of the fraction selected for experiment. If we select that portion boiling steadily between 160° and 170°, we shall have a bromine-compound of the formula $C^{12}H^{12}Br^2$; but if the boiling-point of the naphtha lies between 180° and 190° the bromine-compound will be $C^{14}H^{14}Br^2$. It is exceedingly remarkable that if either of these substances be treated alternately with alcoholic potash and sodium, the original hydrocarbon is regenerated. By the mode of operating indicated above, it is possible, therefore, to obtain two out of the three series of hydrocarbons in a pure state. The third, namely, the benzole series, must be recognised by obtaining products of decomposition.

The acids and bases accompanying the hydrocarbons in Boghead-naphtha have not been fully investigated; it has, however, been ascertained that certain members of the phenole series of acids and pyridine class of bases are always present. The quantities present in the naphtha of commerce are small in consequence of the purification of the fluid by the agency of oil of vitriol, followed by a treatment with caustic soda.—C. G. W.

NAPHTHA, BONE. *Syn.* Bone Oil; Dippel's Animal Oil. This fluid is procured in large quantities during the operation of distilling bones for the preparation of animal charcoal. The hydrocarbons of bone oil have not as yet been examined, but it has been found that the benzole series are present, accompanied by large quantities of basic oils. The acid portions are also uninvestigated. The bases have been very fully studied by Dr. Anderson, who discovered in bone oil the presence of no less than ten bases, several of them being quite new.

The odour of bone oil is exceedingly offensive and difficult of removal. It does not arise entirely from the presence of the powerfully-smelling bases, for even after repeated treatment with concentrated acids it retains its repulsiveness. This is partly owing to the presence of some unknown neutral nitrogenous bodies. When a slip of deal wood is moistened with hydrochloric acid and held over a vessel of crude bone oil, it rapidly acquires a deep crimson tint. This is in consequence of the presence of the extraordinary basic substance pyrrol. The latter, when in a crude state, possesses a most disgusting smell, so much so, that the offensiveness of bone oil was at one time mainly attributed to its presence. It has, however, been discovered that pyrrol when perfectly pure has a most fragrant and delightful perfume, somewhat recalling that of chloroform, but still more pleasing.

The basic portion of bone oil may be extracted by shaking it up with moderately strong oil of vitriol. This must be done with precaution, as large quantities of gases are evolved, consisting of carbonic acid, hydrosulphuric and hydrocyanic acids. The fluid when permitted to repose separates into two layers, the upper being the purified oil, and the lower the acid solution of the bases. The latter being separated is to be distilled until about one-third has passed over. This distillate will contain the chief portion of the pyrrol. The head of the still is then to be removed and the fluid boiled for some time to remove the last trace. The acid solution, after filtration through charcoal, is to be supersaturated with lime and distilled. The distillate contains the whole of the bases. The apparatus should be so arranged that those bases which are excessively volatile, and consequently come over as gases, may be received in hydrochloric acid. The hydrochloric solution and the oily bases are to be examined separately. The former is to be evaporated carefully to the crystallising point, and then allowed to cool. By this means the ammonia may be removed by crystallisation as chloride of ammonium.

When no more sal-ammoniac can be obtained by crystallisation, the mother-liquid is to be treated with potash, in an apparatus so arranged that any gaseous products evolved may be collected in hydrochloric acid. The retort must have a thermometer in the tubulature to enable the temperature to be properly regulated. All the bases distilling below 212°, are to be received in hydrochloric acid, and their presence demonstrated by converting them into platinum salts, and fractionally crystallising. The bases distilling above 212°, are to be separated by fractional distillation. An examination of the hydrochloric solution will, according to Dr. Anderson, demonstrate the presence of methylamine, ethylamine, propylamine, butylamine, and amylamine. The following table contains the names and physical properties of the bases which are contained in that portion of the basic oil which distils above 212°. The amylamine, and even the propylamine, can be separated from the basic oils, by fractional distillation, instead of the fractional crystallisation of platinum salts, but the latter involves less labour.

Table of the Physical Properties of the Pyridine Series of Bases.

Base	Formulæ		Boiling Point	Density at 32°	Vapour-Density	
					Experiment	Calculation
Pyridine .	$C^{10}H^5N$	$\mathbf{C^5H^5N}$	242°	0·9858	2·916	2·734
Picoline .	$C^{12}H^7N$	$\mathbf{C^6H^7N}$	275°	0·9613	3·290	3·214
Lutidine .	$C^{14}H^7N$	$\mathbf{C^7H^7N}$	310°	0·9467	3·839	3·699
Collidine .	$C^{16}H^{11}N$	$\mathbf{C^8H^{11}N}$	356°	0·9439	...	4·137

Bone oil will not become very valuable as a naphtha for general purposes until some cheap method of removing its odour has been discovered. The *Oleum animale Dipellii* of the older chemists and pharmaceutists was prepared by distilling bones; it was very similar in properties to bone oil.—C. G. W.

NAPHTHA, CAOUTCHOUC. *Syn.* Caoutchoucine; Caoutchine. Caoutchouc, by destructive distillation, yields several hydrocarbons, the accounts of which are contradictory. By repeated rectifications they may be separated into fluids of steady boiling-points. The late Dr. Gregory succeeded in obtaining a fluid hydrocarbon from caoutchouc which distilled at 96°, but when treated with sulphuric acid, and the fluid separated by means of water, another hydrocarbon was obtained boiling at 428°. It is most probable, however, that the true composition of caoutchoucine has not yet been made out. This will appear by consulting the analyses yet made, many of them indicating too low a hydrogen for the C^nH^n series, and more nearly approximating to $n\,(C^5H^4)$. It is quite plain, however, that caoutchine is, in every sense of the term, a naphtha. Caoutchine is one of the best solvents known for india-rubber.—C. G. W. See CAOUTCHOUC.

NAPHTHA, COAL. Ordinary coal-naphtha is the first product in the distillation of coal-tar. The latter is placed in large iron stills, holding from 800 to 1,500 gallons, and distilled by direct steam. The first distillate is about 850° S. G. When 950° S. G. is made, all the naphtha or *light oil* is obtained. The distillate from 950° to 1000° S. G. is the *middle oil*; above that to about 106° S. G. is the *heavy oil.*

The residue obtained in the first distillation is run off into cisterns or tar ponds to allow of the removal of the water. This residue is called boiled tar. Pitch oil may be obtained from it by distillation by the naked fire, every 1,000 gallons will yield about 320 gallons of pitch oil. The residue of pitch in the still is run out while in a melted state. The rough coal-naphtha contains a great number of impurities of various kinds; the principal cause of the foul odour being the organic bases described in the article NAPHTHA, BONE. To remove these the naphtha is transferred to large cylindrical vessels lined with lead. These vessels contain a vertical axis passing down them, supporting blades of wood covered with lead, and pierced with holes. The axis or shaft has, at its upper end, a crank to enable it to be rotated. The naphtha having been run into the vessel, sulphuric acid is added, and the shaft with its blades made to revolve. By this means the naphtha and acid are brought into intimate contact. The whole is then allowed to settle, and the vitriol which has absorbed most of the impurities, and acquired, in consequence, a thick tarry consistence, is run off. This acid treacly matter is known in the works as 'sludge.' The naphtha floating above the sludge is then treated a second time with acid, if the naphtha be required of good quality. During the process, the naphtha acquires a sharp smell of sulphurous acid, and retains a certain amount of sulphuric acid in solution. The next process is to treat it with solution of caustic soda to remove these impurities. This may be effected in an apparatus similar to the first. The naphtha, after removal of the caustic liquor, is next run off into a still, and rectified; it then forms the coal-naphtha of commerce.

Coal tar of commerce is derived mainly from the rich cannels, or from the tars made from coal in the London gas-works, or from the gas-works of the English towns. The latter tar is richer in naphtha than the London; while the tar from the Scotch cannels yields from seven to thirteen per cent. of crude naphtha of a specific gravity of about ·930, which is blown from it by steam introduced into the still. A still containing 2,500 gallons of the other tars would yield on an average forty gallons.

The commercial value of naphtha has fluctuated since the extensive introduction of the coal-tar colour industries, according to their varied fortunes during the last twenty years.

The more or less volatile varieties were sought after just as the varied shades of aniline, the manufacture of which they suited, headed the market. By a series of fractional distillations, both with wet and dry steam, washings with sulphuric acid (specific gravity 1·845), a series of naphthas, more or less rich in benzole, and containing other valuable products are obtained. The naphtha which flows over at a temperature up to 204° Fahr. is called 90 per cent. benzole; that flowing between 204° and 210°, is designated 80 per cent. benzole, and is again fractionally distilled up to 204°; while the residue, on being treated with high-pressure steam, yields a quantity of 40 per cent. naphtha.

Subjecting a charge of 1,587 gallons of crude naphtha and light oil to the series of operations indicated, we obtain, first 897 gallons of once-run naphtha, and 56 gallons of the last runnings, the remaining 634 gallons being only fit to mix with dead oil. The 897 gallons of once-run naphtha yields, after purification by sulphuric acid, 301 gallons of 90 per cent. benzole, 195 gallons of 40 per cent., 237 gallons of solvent naphtha, 12 gallons of last runnings, and 152 gallons of residuum.

The 40 per cent. naphtha contains also toluol and xylol, and is most suitable for making aniline red; the 90 per cent. variety is best adapted for the manufacture of aniline blue or black.

In describing coal-naphtha, we shall take a cursory review of the nature and properties of most of the substances produced by the distillation of coal-tar. It will be unnecessary here to enter into a minute description of the acids existing in coal-tar, inasmuch as they have already been treated of in the article CARBOLIC ACID.

On the hydrocarbons of coal-naphtha.—The following are the principal constituents of those coal-naphthas the boiling-points of which range between 190° and 350°:—

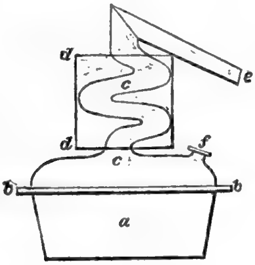
Base	Formulæ		Boiling Point	Specific Gravity
Benzole . . .	$C^{12}H^{6}$	$\mathbf{C}^{6}\mathbf{H}^{6}$	177°	0·850 at 60°
Toluole . . .	$C^{10}H^{8}$	$\mathbf{C}^{5}\mathbf{H}^{8}$	230°	0·870
Xylole . . .	$C^{16}H^{10}$	$\mathbf{C}^{8}\mathbf{H}^{10}$	259°	
Cumole . . .	$C^{18}H^{12}$	$\mathbf{C}^{9}\mathbf{H}^{12}$	304°	
Cymole . . .	$C^{20}H^{14}$	$\mathbf{C}^{10}\mathbf{H}^{14}$	347°	0·861 at 57°

The fluid hydrocarbons boiling above this point have not been well studied. Ordinary coal-naphtha, in addition to the above hydrocarbons, contains traces of the homologues of olefiant gas, alluded to in the article Naphtha.

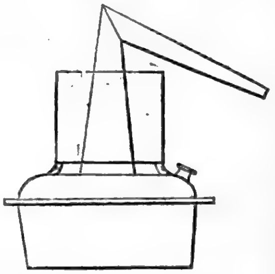
All the above-mentioned hydrocarbons may be separated from each other by careful and sufficiently numerous fractional distillations. It is proper before considering them as pure, to shake them up several times with oil of vitriol, and, after well washing first with water, and afterwards with an alkaline solution, to dry them very carefully with chloride of calcium or sticks of potash. It will be observed that in the above table the specific gravities of the hydrocarbons are not in harmony; this arises from the fluids upon which the experiments were made not having all been procured from the same source; for it has been found that the same bodies, as procured from different sources, often present small but appreciable differences in odour, density, boiling-point, and other physical properties.

The benzole of coal-naphtha may almost entirely be separated by distilling in an apparatus first devised for the purpose by Mr. C. B. Mansfield. The annexed figures from G. Williams's 'Handbook of Chemical Manipulation,' illustrate the vessels he employed for the purpose. *Fig.* 1545 consists of a copper or tinned iron still, *a*, holding about two gallons. The flange *b b*, is merely to support the apparatus in the ring of a gas or charcoal furnace, preferably the former. A wide worm, *c c*, passes through the top of the still into a water-tight cistern, *d d*. The worm ends in a discharge-pipe, *e*. The latter is to be attached to a common worm tub containing cold water. The crude benzole, or coal-naphtha, is to be placed by means of the opening *f* into the still, and all the joints of the apparatus being closed, and effectual condensation insured, the fire is to be lighted. The naphtha soon begins to boil, but nothing comes over, because the water in *d d* effects condensation. In a short time, however, the water in *d d* begins to get warm, and, as soon as 177° is reached, benzole begins to come over, and is perfectly condensed in a second worm, kept cold by means of water. It is plain that as the fluids of higher boiling-points begin to come over, the water in *d d* will boil, but distillation then ceases entirely. The reason of this is, that nothing can make the head *c c* hotter than 212°, because of its being surrounded with water. All hydrocarbons that are not volatile at 212° are consequently condensed there, and fall back into *a*. The benzole distilling over is quite pure enough for all ordinary purposes. It may, if required very pure, be rectified a second time in the same apparatus, taking care that the head does not get hotter than 180° or 190°. If the benzole is wanted absolutely free from its accompanying hydrocarbons, it must be purified by freezing. For this purpose the rectified benzole is to be placed in a thin glass or metal vessel, and surrounded with snow or pounded ice mixed with salt. The whole apparatus is to be surrounded with sawdust and covered with woollen cloths to prevent access of heat. As soon as the benzole is frozen, it is to be placed in a funnel and allowed to drain. The solid mass when thawed is pure benzole. By this mode of proceeding, a considerable quantity of fluid is always accumulated, which refuses to freeze and yet boils at the proper temperature for benzole. G. Williams found it to contain a small quantity of the C^nH^n series of hydrocarbons (homologous with olefiant gas). Mr. Church states it to contain benzole in a peculiar condition; he calls it parabenzole. The presence of the C^nH^n series may always be proved by the readiness with which the fluid decolourises bromine-water.

1545



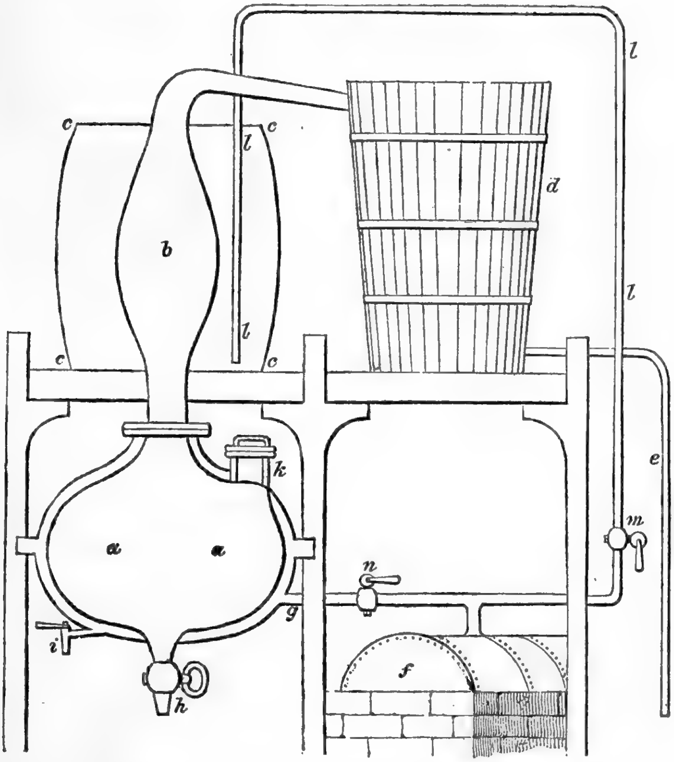
1546



A similar form of apparatus for rectifying benzole, and one that answers almost as well, is that represented in *fig.* 1546. It will be seen that the worm *c c* of *fig.* 1545 is replaced by a straight tube. The mode of use is precisely the same.

Where the benzole is to be extracted from coal-naphtha on the large scale, the following apparatus will be found convenient:—The boiler *a a*, *fig.* 1547, surrounded by a steam-jacket, is connected at its upper extremity with a head, *b*, answering to the worm *c* in *fig.* 1545. The head plays into the worm-tub *d*; the benzole being conveyed by the exit-pipe, *e*, to the reservoir, or close tank, in which it is to be stored. The tub, *c c c c*, contains water to condense the hydrocarbons which are to be removed from the benzole. In order to save time, it is convenient at the commencement of the operation to heat the water in *c c c c* to about 170°; this is effected by means of the steam-pipe *l l l*, which is connected with the boiler *f*. The steam is admitted to the jacket of the still by means of the pipe *g*. The steam can be regulated or stopped altogether by means of the stopcock *n*. The cock *m*, is to regulate the admission of steam to the vessel *c c c c*. The man-hole is represented at *k*. A small cock to allow the condensed water in the jacket to be run off, is seen at *i*. Unless the naphtha is of the best quality the benzole will be difficult to extract by the heat of the jacket alone. It will then be necessary to send direct steam into *a a*. When no more benzole comes over, the remaining naphtha is to be run out of the still by the stopcock *h*. Although the boiler *f* is, for the sake of space, represented in the figure as if placed beneath the support of the condenser or worm-tub, it should in practice be removed to a considerable distance for fear of the vapour of the hydrocarbon reaching the stoke-hole and causing an explosion. The condenser *b* may be arranged in the form of a worm like *c* in *fig.* 1545, but the precaution is scarcely necessary if the chamber at *b*, *fig.* 1547, be made sufficiently capacious. The benzole obtained in the above apparatus is, of course, contaminated with toluole; if, however, the rectification be repeated, the water in the chamber *c c c c* not being permitted to become hotter than 180° Fahr., the resulting benzole will be almost pure. One distillation is amply sufficient for the preparation of the commercial article.

1547



A rectifying column somewhat like Coffey's still may also be employed for preparing benzole.

The less volatile naphtha remaining in the still is by no means valueless; it is adapted for almost all the purposes for which ordinary coal-naphtha is applicable. By removing the fluid by the tap *h*, and distilling it in an ordinary still, a very good coal-naphtha of a density of about 0·870 will be obtained.

It is extremely curious that naphthas which contain large quantities of naphthaline will often distil without the latter crystallising out. It is volatilised in the vapour of the naphtha, and therefore escapes observation. But if a little chlorine be poured into the fluid, or if a little chloride of lime be added, followed by an acid, and the fluid be then distilled, the naphthaline will come over in the solid state, so that it can be removed by mechanical methods. It does not appear to be due to the formation of Laurent's chloride of naphthaline, for the product contains only traces of chlorine.

Benzole has been much used of late to remove greasy and fatty matters from cotton, wool, silk, and mixed fabrics. It is by no means essential that the benzole should be absolutely pure for this purpose. By this it is meant that the presence of naphthas, boiling somewhat above 177°, does not materially affect the usefulness of the fluid. If, however, the naphtha is to be employed for removing greasy stains from dresses, gloves, or other articles to be worn, the purer and more volatile the hydrocarbon, the more readily and completely the odour will be removed by evaporation. Mr. F. C. Calvert patented the application of benzole to some purposes of this kind. He first purified the naphtha by means of sulphuric acid and caustic alkalis in the usual manner, and then rectified it at a temperature not exceeding 212°.

For this purpose the apparatus described in *fig.* 1547 will be found well suited. The inventor applies the rectified coal-naphtha, or nearly pure benzole, to the following purposes:—1st, for removing spots and stains of grease, *i.e.* fatty or oily matters, tar, paint, wax, or resin, from cotton, woollen, silk, and other fabrics, when, in consequence of its volatility, no mark or permanent odour remains. 2nd, for removing fatty or oily matters from hair, furs, feathers, and wools, and for cleaning gloves and other articles made of leather, hair, fur, and wool. 3rd, for removing the fatty matters which exist naturally in wool. 4th, for removing from wool, tar, paint, oil, grease, and similar substances used by farmers for marking, salving, and smearing their sheep. 5th, for cleansing or removing the oily or fatty matters which are contained in cotton-waste that has been used for cleansing or wiping machinery or other articles to which oil or grease has been applied. In order to remove the above matters by means of coal-naphtha, the articles, if small, are merely rubbed with it. On the large scale the matters to be operated on are placed in suitable vessels, and the naphtha is run in. After contact for some hours the fluid is run off, and the fabrics are passed through squeezers and submitted to strong pressure to remove the greater portion of the benzole or naphtha. The naphthas which run out are distilled off, so that the greasy matters may be preserved and used for lubricating machinery or other purposes.

Furniture paste may also be made from light coal naphtha or benzole by the following process:—One part of wax and one of resin is to be dissolved in two parts of the hydrocarbon, with the aid of heat. When entirely dissolved, the whole is allowed to cool, and is then fit for use.

Naphthaline is used for the preparation of lamp-black, but the quantity employed for that purpose is but small. The quantity annually produced by the various gas-works is enormous. Its odour and volatility prevent its being applied to lubricating purposes. It often happens that much valuable time is lost by unscientific operators in endeavouring to remove the smell from such substances as naphthaline; they forget that the odour of a body of this class is a part of itself, and cannot be removed without its destruction. It is possible that the compounds of naphthaline may one day be applied to useful purposes. By treating naphthaline with excess of chlorine, and removing fluid substances with ether, a crystalline paste is obtained. This paste, dissolved in boiling benzole and allowed to repose, deposits beautiful rhombohedral crystals, often of large size. They have exactly the form of Iceland spar, and, like that substance, possess the power of double refraction. When nitronaphthaline is treated with acetic acid and iron filings in the same manner as that employed by M. Béchamp for the production of aniline, a base is obtained of the formula $C^{20}H^{9}N$; it is called Naphthalamine. It is, therefore, isomeric with cryptidine, but has no other point of resemblance.

If treated with nitric acid, naphthaline yields phthalic acid, and this by elimination of carbonic acid may be either converted into benzole or into benzoic acid. Benzoic acid is now derived commercially from naphthaline.

The relation which appears to exist between naphthaline and alizarine is also very interesting. Alizarine is now prepared artificially from anthracene or paranaphthaline, by processes described under the articles ALIZARINE and ANTHRACENE.

Naphthalamine, which is the base corresponding to aniline, is now manufactured in the same way as that body is from benzole. It yields beautiful commercial dyes, viz.: Martius yellow, Magdala red, Naphthaline violet, and Naphthaline blue.

It is said that naphthaline has been employed with advantage in the treatment of psoriasis. M. Emery states that it succeeded in twelve out of fourteen cases. In the two where it failed the one patient was a woman thirty years of age, who had been afflicted for eight years with *psoriasis gyrata*; the other patient was a young man who had suffered for several years with *lepra vulgaris*. In the latter case, two months' treatment having effected no good, pitch ointment was substituted, which effected a cure in two months. The naphthaline was employed in the form of ointment in the strength of ½ or 1 drachm of lard. The application is sometimes, however, attended with severe inflammation of the skin, which must be relieved with poultices.

The dead oils, as the less volatile parts of coal-tar are called, contain several substances, the nature of which is very imperfectly known. Among them may be mentioned pyrene and chrysene. The former has been examined by Laurent, who gives the formula $C^{30}H^{12}$ for it. They are found in the very last portions that pass in the distillation of coal-tar. They are also said to be produced during the distillation of fatty or resinous substances. The portions which distil last are in the form of a reddish or yellowish paste, which rapidly darkens in colour on exposure to light. Ether separates it into two portions, one soluble, containing the pyrene, the other insoluble, containing the chrysene. The pyrene may be obtained by exposing the etherial solution to a very low temperature, which will cause it to crystallise out. The composition of pyrene is, according to Laurent,—

	Experiment.	Calculation.	
Carbon . . .	93·18	C^{30}	93·7
Hydrogen . . .	6·11	H^{12}	6·3
	99·29		100·0

The portion insoluble in ether consists of chrysene in a tolerably pure state. G. Williams found that it crystallises on cooling from a solution in Boghead naphtha, in magnificent yellow plates, with a superb lustre resembling crystallised iodide of lead. The following are the results of its analysis. His combustion was made upon chrysene crystallised as above:—

	Laurent.		C. G. W.	Calculation		
Carbon . .	94·83	94·25	94·63	94·74	C^{18}	108
Hydrogen .	5·44	5·30	5·37	5·26	H^{6}	6
	100·27	99·55	100·00	100·00		114

See Chrysene.

No commercial use has been yet devised for these interesting bodies; which are also bye-products in paraffin refineries. But the brilliant discoveries of Graebe and Lieberman have raised anthracene from the category of waste materials. In 1868 they obtained anthracene from alizarine, and in the following year they were able to disclose a process for the manufacture of the valuable dye from the unsavoury coal-tar product. A large extension of the coal-tar colour manufacture has ensued. Anthracene is obtained from the heavier coal oils, which when exposed to the action of a powerful freezing mixture, often deposit a mass of crystals only partly soluble in alcohol. The soluble portion consists of naphthaline; the other portion is anthracene, or paranaphthaline. It appears, from the analyses which have been made, to be isomeric with naphthaline. It fuses at 356°, and boils at about 580°. The density of its vapour, determined at 848°, was 6·741°, agreeing very well with the formula $C^{30}H^{12}$, which requires 6·643. This formula is one and a half times naphthaline, thus: $C^{20}H^{8} + C^{10}H^{4} = C^{30}H^{12}$. For a description of the methods by which anthracene is now prepared from coal-tar, and alizarene from anthracene, the reader is referred to these articles respectively, and to the Supplement to Watts's 'Dictionary of Chemistry.'

Metanaphthaline is a peculiar substance which appears to be closely related to the above products. It is formed during the manufacture of resin gas. It is a fatty substance fusing at 158°, and distilling at about 617°; it is at present but little known.

The following Table, taken from *Traité des Dérivés de la Houille*, by Gerard and De Laire, epitomises the operations of French tar-distillers:—

First Distillation of Coal in the Retorts.

Gas. Tar. Coke.

Second Distillation of the Tar.

1. Light oils (boiling 30° to 150° Cent.). 2. Medium or creasote oils (boiling 140° to 200° Cent.). 3. Anthracene oils, or heavy oils, containing naphthaline and anthracene (boiling 200° to 350° Cent.).

THIRD DISTILLATION.

Light Oils.

Into 2 fractionals.

No. 1. That which passes over, up to 140° Cent., constituting naphtha.

No. 2. That which passes over, above 140° Cent., is mixed with No. 2 fractional distillation of the middle oils.

Middle Oils.

Into 3 fractionals.

No. 1. That which passes over, up to 130° Cent., is remixed with the naphtha.

No. 2. That which passes betwixt 130° and 200° = rectified creasote oil.

No. 3. That which passes over, above 200° Cent., is counted anthracene oil.

TREATMENTS BY WASHING.

Rectified Light Oils or Naphthas.

(39° to 140° Cent.). Subjected to

1 washing with pure water.
2 washings with sulphuric acid.
2 washings with water.
1 washing with soda.
2 washings with water.

Middle Rectified Oils.

(140° to 200° Cent.) Subjected to

1 washing with pure water.
2 washes with sulphuric acid.
2 washes with pure water.
1 washing with soda.
2 washes with pure water.

Crude Heavy Anthracene Oils.

(200° to 350° Cent.) Subjected to
1 wash with pure water.
2 washes with hydrochloric acid.
1 wash with pure water.
1 wash with soda.
2 washes with water.

FOURTH DISTILLATION.

Naphtha.

Into 4 fractionals.

No. 1. That which passes betwixt 39°— 80° Cent.
No. 2. " " 80°—115° Cent. benzole.
No. 3. " " 115°—150° Cent.
No. 4. " a little over 150° Cent.

Middle Rectified Oils.

Into 2 fractionals.

No. 1. That which passes 140° to 190° Cent.

No. 2. That which passes over 190° Cent. is mixed with the heavy oils.

Pure Heavy Oils.

Into 3 fractionals.

No. 1. That which passes from 215° to 230° Cent.

No. 2. That which passes from 230° to 290° Cent.

No. 3. That which passes from 300° to 340° Cent.

The *Light Oils* or *Naphthas* contain the following bodies:—

	Boiling-point. Cent.
Ammonia and ammoniacal salts	...
Amylene	39°
Traces of propylene, butylene dissolved in their homologous liquids	...
Caproylene or hexylene	55° to 70°
Hydruret of hexyle	68°
Petinine	80°
Benzine	82° to 83°—0·850
Œnanthylene or heptylene	94°
Toluene	105° to 108°
Parabenzine	97° to 98°
Hydruret of octyle	116° to 115°

	Boiling-point. Cent.
Xylene	127° to 128°
Picoline	133°—0·955
Cumene	151°
Hydruret of decyle	158°
Pyridine	150°
Cymene	175°
Traces of phenic acid	...

The various treatments specified in the Table are to remove several of these bodies, which give the crude naphtha its offensive odour, and hinder its retaining a permanent white colour. In the various acid and alkaline treatments 5 per cent. of ordinary sulphuric acid is used, which is counteracted by 2 to 3 per cent. of caustic soda of a density 1·305.

The *Middle Oils*, after their first rectification, and their augmentation with the fractional distillation of the heavier naphthas, contain the following bodies:—

	Boiling-point		Boiling-point
Picoline	133°	Aniline	182°
Pyridine	150°	Phenic acid	187°
Cumene	145° to 151°	Parvoline	188°
Lutidine	154°	Toluidine	198°
Eupion	169°	Cresylic acid	203°
Cymene	179°	Coridine	211°
Collidine	175°	Naphthaline	from 79° from 218°

Just 5 per cent. of sulphuric acid is given at each of the two treatments of the middle oil; and the amount of soda used depends on the quantity of cresylic or phenic acids—a very variable amount—the individual oil may contain. To estimate the quantity of phenic acid, agitate 4 or 5 kilogrammes of the middle oil with an excess of caustic soda of specific gravity 1·305, for an hour or two; allow it to repose; then decant the soda-liquor; wash it with hot water; then filter; treat the clear filtrate with hydrochloric acid, and the phenic acid will separate. As the equivalent of phenic acid ($C^6H^6O = 94$) is about 1½ that of soda ($Na^2O = 62$), 1 part of soda should fix 2 parts of the acid. Part of those middle oils is also used in dissolving caoutchouc.

The *Heavy Oils*, until recent discoveries of the utilisation of the waste bodies anthracene and naphtha, were not usually distilled. Their distillate betwixt 215° and 230° is almost all naphthaline; that betwixt 290° and 320° is principally anthracene.

The *Heavy Oils* contain:—

	Boiling-point
Aniline	182°
Phenic acid	187°
Parvoline	188°
Cresylic acid	203°
Phlorylic acid	203°
Coridine	211°
Naphthaline	217° to 218°
Rubidine	230°
Quinoleine or leucoline	235° to 237°
Viridine	251°
Lepidine	260°
Anthracene and paranaphthaline	310° to 359°
Chrysene	...
Pyrene	...

The proportions of acid and alkali in this treatment are 6 per cent. of soda and 10 per cent. of hydrochloric or sulphuric acid. In order to expiscate the odour, this oil, after distillation, is treated with 4 per cent. of sulphate of iron.

The rectified oil may be used for greases, for creasoting railway-sleepers, as an antiseptic, or for fuel or gas-making.

NAPHTHA, NATIVE. In a great number of places in various parts of the world, a more or less fluid inflammable matter exudes. It is known as Persian naphtha, Petroleum, Rock-oil, Rangoon tar, Burmese naphtha, &c.

The American petroleum consists in its more volatile portions of amyl, hydrogen, hydride of amyl, C^5H^{12} boiling at 68°, and hydride of caproyl C^6H^{14} boiling at 92°;

the portion capable of being safely used in lamps is represented by the hydrocarbons C^7H^{16} and $C^{12}H^{26}$. The higher series of the marsh-gas group, which are composed according to the formulæ $C^{20}H^{42}$ and $C^{27}H^{56}$, exhibit a butter-like consistency and belong to the paraffins met with in petroleums. Rangoon oil assumes at ordinary temperatures the consistency of butter.

Messrs. Warren De La Rue and Hugo Müller find the fluid to consist of two principal series of hydrocarbons, namely, the benzole class and another, unacted upon by acids, and apparently consisting of the radicals of the alcohol. In addition to the fluid hydrocarbons, Burmese naphtha contains a considerable quantity of paraffin.

Burmese naphtha or Rangoon tar is obtained by sinking wells about 60 feet deep in the soil; the fluid gradually oozes in from the soil, and is removed as soon as the quantity accumulated is sufficient. The crude substance is soft, about the consistence of goose grease, with a greenish brown colour, and a peculiar but by no means disagreeable odour. It contains only 4 per cent. of fixed matters. In the distillations De La Rue and Müller employed superheated steam for the higher, and ordinary steam for the lower temperatures. At a temperature of 212°, 11 per cent. of fluid hydrocarbons distil over; they are entirely free from paraffin. Between 230° and 293° Fahr., 10 per cent. more fluid distils, containing, however, a very small quantity of paraffin. Between the last-named temperature and 320° Fahr., the distillate is very small in quantity, but from that to the fusing point of lead, 20 per cent. more is obtained. The latter, although containing an appreciable amount of paraffin, remains fluid at 32° Fahr. At this epoch of the distillation, the products begin to solidify on cooling, and 31 per cent. of substance is obtained of sufficient consistency to be submitted to pressure. On raising the heat considerably, 21 per cent. of fluids and paraffin distil over. In the last stage of the operation, 3 per cent. of pitch-like matters are obtained. The residue in the still consisting of coke containing a little earthy matter, amounts to 4 per cent. We thus have as the products in this very carefully-conducted and instructive distillation:—

Below 212°	Free from paraffin	11·0
230° to 293°	A little paraffin	10·0
293° to 320°		
320° to fusing point of lead	Containing paraffin, but still fluid at 320°	20·0
At about the fusing point of lead	Sufficiently solid to be submitted to pressure	31·0
Beyond fusing point of lead	Quantity of paraffin diminishes	21·0
Last distilled	Pitchy matters	3·0
Residue in still	Coke containing a little earthy impurity	4·0
		100·0

All the above distillates are lighter than water. Almost all the paraffin may be extracted from the distillates by exposing them to a freezing mixture. In this manner no less than between 10 and 11 per cent. of this valuable solid hydrocarbon may be obtained from Burmese naphtha.

Naphtha appearing closely to resemble the above is found at Alfreton, Amiano (Duchy of Parma), Baku (borders of the Caspian), Barbadoes, Clermont (France), Gobian, near Bezières (France), Galicia, Neufchâtel (Switzerland), Tegernsee (Bavaria), Trinidad, United States, Val di Noto in Sicily, Wallachia, Zante, St. Zibio (Modena), Sehndee near Hanover, near Hamburg, Kleinschöppenstadt, Brunswick, in the Pyrenees and other portions of Spain and France. Petroleum, well salt, and combustible gases are associated together in the Bavarian Alps, in Tuscany, Modena, Parma, the Carpathian Mountains, in America, and other localities. As marsh-gas is given off from beds of rock-salt some chemists have suggested that CH^4 might yield by condensation the homologous hydrocarbons C^6H^{14} and C^7H^{16} forming the bulk of the volatile portions of petroleum and paraffin. Naphtha was one of the ingredients said, by some old authors, to enter into the composition of the Greek fire.—C. G. W.

Naphtha was originally a mineralogical term; but much confusion has arisen in its application, or in that of its mineralogical synonym Petroleum, to articles of commerce or manufacture. The first distillate of coal-tar resembled in appearance and in some properties the fluid described as oozing in many places from the earth; hence the apparent propriety of adapting an old name for the new manufactured product. But both articles have now become important foundations for two very different industries, and it has been found that the earth-oil cannot give benzole, the coal-tar colour producer. So it has been tacitly agreed by technologists to give the name *Naphtha* to the distillate from coal-tar, whilst *Petroleum* is assigned to the natural products; for though specimens of these may be chemically different, they serve the same manufacturing purposes and are commercially looked upon as one body. But as the similarity in the processes of manufacture of both bodies must strike an intelligent workman, we need not feel surprised when he calls alike the products of shale petroleum, or coal-tars from the still naphthas. The distinction, moreover, is convenient; as the products of the first two bodies serve different technical purposes from the subsequent ones. They have also become the subject of legislative provision on account of the lamentable accidents which they have sometimes occasioned; though the confusion in terminology is well illustrated in a recent enactment which designates as petroleum all bodies from rock-oil, schists, or peat inflaming below 100° Fahr. It has been generally thought that the application of the term *spirit* would be a convenient substitute for shale or petroleum naphtha.

According to Wiederhold, crude or native naphtha gives by fractional distillation:—

Petroleum spirit	48·6 per cent. of	0·70 spec. grav.	boiling at	100° Cent.
	45·7 „	0·73 „	„	200° „
Refined petroleum	5·7 „	0·80 „	above	200° „

The lightest distillates of American petroleum, Sherwood oil, or shale have been much investigated in regard to use as anæsthetics or as carburetters. Names have thus been given to the varied fractional distillates. Kleinschmidt of St. Louis specifies the following;—

				Beaumé.	
Oils distilling over below	37·7°	specific gravity	·0° – ·60°	= 90°–97°	= Rhigolin
„ „ at	76·6	„	0·63 – 0·61	= 80–90	= Gasolin
„ „ „	137·0	„	0·67 – 0·63	= 70–80	= Naphtha
„ „ „	148·0	„	0·73 – 0·67	= 60–70	= Benzine
„ „ „	183–219	„	0·78 – 0·82	= 40–60	= Kerosen.

The late Sir James Simpson took great interest in the anæsthetic powers of the first series; on account of them petroleum gained its healing repute amongst the American Indians; applied externally they soothe neuralgic complaints.

Gasolin is mainly relied on as the carburetting agent by several new patent gas companies who thus purpose to enrich common coal-gas, water-gas, or atmospheric air. Spirit of specific gravity of about 0·650 and with a boiling-point of 58° Cent. is preferred for this purpose, and as this spirit, which the preceding analysis shows constitutes so large an item in crude petroleum, is too dangerous to burn in common lamps, it is sold at the price of a waste product. It is believed that one gallon of spirit will carburet 500 cubic feet of gas, raising it in luminosity to 30 or 33 candle-power of flame. The opposing elements of odour and danger may stand in the way; but the same process may be adapted in using this spirit for heating or smelting operations. Mr. Wills, F. C. S. gives the following calculations founded on Dalton's law for ascertaining the vapour-tension of liquids. ('Journ. Soc. of Arts, No. 1070, vol. xxi.)

Table of percentage of vapour of petroleum spirit of a specific gravity ·650 *present in air or other medium at different temperatures.*

Temperature.		Percentage.	Temperature.		Percentage.
−10° Cent.	(14° Fahr.)	5·7	−15° Cent.	(60° Fahr)	22·0
0 „	(32 „)	10·7	20 „	(68 „)	27·0
10 „	(50 „)	17·5	40 „	(104 „)	39·0

This diffusibility through air in the state of vapour of petroleum has occasioned many lamentable accidents, to prevent which various legislative measures have been passed. When a light is applied to a common paraffin-oil lamp, in which the oil is at once converted into vapour, ignition will occur. Explosion will also supervene on shipboard or in a room, in which a mixture of common air and hydrocarbon-vapour, whether from low specific gravity, or from the construction of the reservoir-cell, have been allowed to accumulate in the proportions which cause coal-mine or domestic gas mixed with air to explode. Petroleum and the paraffin oils alike consist of a series of oils bound together by links and very similar in composition. But the first members of the series are very easily detached from the others, and their vapours come off at ordinary temperatures. Mere specific gravity does not, as was once thought, determine the safety of an oil. The specific gravity of mineral oil ranges from 814° to 830°, the extreme point at which it easily ascends a wick without charring it. But petroleums of 800° have been shown perfectly safe by the tests of flash-point and firing-point; whilst others standing at higher numbers on the hydrometer have not stood them. In America the original way of testing the firing-point of oils is by placing a light in the open vessel containing them, which is being also heated, and noting the exact degree on a thermometer whose bulb is also immersed in the fluid, when flame appears on its surface. In this country, again, legislation is based on the fact that light vapours arise many inches from the surface of the oil, and can be ignited there long before the body of the oil takes fire. In the open test which was first prescribed by Act of Parliament, the vessel holding the oil was inclosed in a water-bath heated by a spirit lamp, a thermometer again inserted, the whole protected by a screen extending half round the surface of the vessel, and a match, in, say the form of a piece of string, applied a full inch at least above the surface of the oil. In the close test the surface of the oil-holding vessel is covered; openings only being left for the firing-string and the thermometer. There is a difference of 15° to 25° in the firing-point of the two tests; the tests reduce the degrees in the inverse order to that in which they have been given. An American cargo with a firing-test certified at port of transit, will have it diminished about 10° by the open test, and 20° by the close test. The law now stands for Britain prohibiting the sale of petroleum under 100°. It varies in different countries. At Antwerp, which regulates the petroleum importation of Germany, there is no prohibitory enactment. The State of Maine, U. S., specifies 115° igniting test, whilst Massachusetts and Vermont agree on 110° Fahr. (See 'Report of Select Committee of the House of Lords on the Petroleum Bill, 1872.')

Petroleum and paraffin spirits or naphtha have also acquired the synonym of 'turpentine-substitute,' because of their application in varnishes and other house paints; but, as the name implies, cheapness mainly regulates this use.

Hirzel (Spec. A. D. 1863, No. 2987) proposes to extract essences and perfumes, by petroleum spirit, as a substitute for bisulphide of carbon. Others have patented this substance as an extractor of vegetable and animal oils. G. Ville, the French agricultural chemist, shows that were this method applied to the culture of the ordinary oleaginous plants much good would result. If 35 hect. of the colza were treated ordinarily by hydraulic press, 808 kil. of oil would be given; but by the aid of petroleum spirits the produce is increased to 1,039 kil. (See *Les Engrais Chimiques*, par M. G. Ville, tom. ii. p. 176, &c. Paris, 1872).

Ville is inclined to think that from 6 to 8 per cent. of oil is left in seeds after the action of the hydraulic press. Of course where oleaginous plants are mainly grown for their oil and fibre, as in the Western States of America, or where the cake is returned as a manure into the soil, as recommended by G. Ville, this process is commercially available.

Sponge lamps have been suggested to use mineral spirits either as portable gas for illuminants or a quick and ready heating-power. The chandlers last winter exhibited at least two ingenious French contrivances for this purpose. With proper precautions, no danger can supervene. Any other hydrocarbon incautiously managed will cause peril. Turpentine emits a volatile vapour a little above 110° F.; and a can of it kept in a storehouse a little above the boiler is said to have caused an explosion resulting in the famous burning of the steamer 'Amazon.' Other like calamities have been traced to this source. Such volatile oils expand at the rate of 1 in 30 in a temperature of 60° F., that is to say, between 40° F. and blood-heat; other oils of the series expand at correspondingly higher temperatures. The oil which gave its sad pre-eminence to the Abergele accident was a Welsh-made oil of 130 spec. grav., and a high firing-point. When such vapours mix with atmospheric air in the proportion of 1 in 7 or thereabouts, an explosion occurs on the proximity of a light.

On first igniting a paraffin lamp, the heat from the burning wick causes the lighter oils to ascend in vapour. Should the whole contents of the reservoir be too suddenly raised into vapour, manifestly 'there's death in the pot.' A dangerous oil will assume this state at 80° or 90° F., but only a very small portion of a safe oil will vaporise at these temperatures. Dr. Lyon Playfair gave the following evidence before a recent Parliamentary Committee:—'I would burn no oil in my own house, nor would I advise a friend of mine to burn any in his house, under 120° F. as the very minimum, but I should prefer 130°, that is to say, 120° for the vapour, and 130° for the permanent ignition. Oil with a high firing-point gives out more light than the other kind. It burns quite as long and gives out more illumination. A gallon of oil at 130° of permanent ignition, produces 25 per cent. more light than a gallon at 100°. The light from the low-igniting oil is not more at the time it is burning, but those who are accustomed to burn light petroleum, sometimes like it better than heavier and safer oils, as they find that they can manage the wick more easily.'

At an expense of about 2*d*. per gallon, petroleum can be refined so as to be perfectly safe.

The following remarks on the formation of naphthaline from practical gas manufacturers are of considerable interest. Mr. Hyde, at a meeting of the Gas-light Association of the United States held at Cleveland, after generally describing this substance, proceeded to say:—It had a peculiar faintly aromatic odour, not unlike narcissus; it was heavier than water, and was readily dissolved by naphtha. During the fifteen years of his experience as engineer of the Cleveland Gas-light and Coke Company, in the manipulation of the gas varied results had been observed. In the process of condensing and washing the gas, their usual method had been to condense first and then to wash. At one time it was thought advisable to erect a spray-washer between the hydraulic main and the condensers, as was the method in many gas works. Soon after there was observed a rapid accumulation of naphthaline in the drain leading to the tar-well, in the purifiers and pipes about the works, and also in the distributing mains in the streets. At a subsequent period these spray-washers were removed and placed between the condensers and purifiers, used in connection with the purifiers, and very much less naphthaline was crystallised. During the periods mentioned the heats of the benches were what was termed 'high.' During the past cold season there was used with the common bituminous coal from four to eight per cent. of cannel coal. The heats were not high, the gas was kept hot while passing from the retort-house to the condensers—about 150 feet—by encasing the pipe; the condensation was very gradual, by the use of an open-air condenser, and but a small amount of water used in the scrubber and no spray-washer. During this period they had no crystallised naphthaline. It had always been observed that wherever high heats were carried more naphthaline was crystallised than with medium heats; and that when a bench was lightly charged, after being cleaned of carbon and while hotter than usual, naphthaline appeared more abundantly than under ordinary circumstances. His deductions from his experience at the Cleveland works were as follow:—The crystallising of naphthaline was caused first by 'high heats,' and the amount increased by rapid cooling of the gas by contact with cold water, cold pipes, and other rapid cooling; and that naphthaline was more likely to be developed in gas made from slack coal than from lump coal. The remedy he would suggest for the annoyance was the use of a small percentage of cannel coal, in connection with the common bituminous coals, moderate heats, long exposure of the gas to hot pipes or other condensing operations before reaching the cooling condenser; slow cooling of the gas, and scrubbing with a small amount of fresh or ammoniacal water of moderate temperature; and, also, when found necessary, the introduction of a small continuous supply of naphtha into any horizontal pipes about the work after condensation, or into the drips of the inlet and outlet pipes to the gas-holder. The evaporation of the naphtha would dissolve the naphthaline crystals.

Another gas-engineer remarked that high heats had been so constantly upbraided as the parent of naphthaline, and so thoughtlessly and unjustly, that he must try to rescue them from blame. He admitted that high heats undoubtedly place them in a position to be annoyed with the crystal, but so did the use of steam put them in jeopardy from railway accidents. Of late years they had been putting brain-work into their retort-houses faster than into the other apparatus, and the result was the unfortunate crystal under dissection. High heats, low seals, rapid evolution of the gases, hasty removal from the retort, and sudden plunging at a high temperature into the showers of spray-washers, or through yards of chilling condensers, soon gave birth to the lusty and troublesome crystal nuisance that sheds its unthankful favours upon gas managers. The agency of heats in producing naphthaline lies simply in converting into a gas, at a high heat, olefiant qualities, that at low heats pass over as oils. In order to retain this (at that point) easily-condensed volatile oil in a gaseous form, three methods were open to them: they might mix free hydrogen with their coal-gas at a high temperature; they might introduce into their coal-gas, gas made from naphtha; or adopt the plan of having a long connecting main, protected from atmospheric changes, between the hydraulic main and condensing apparatus, so retaining the crude gas as long as possible in contact with its own condensable vapours, and subjecting it to a gradual lowering of temperature. He had made the practice of introducing the water into his condensers at the 'outlet' end, and taking the overflow from the 'inlet' end, so causing the gas to come first in contact with pipes somewhat higher tempered than he could otherwise do, and so continuing his scheme of gradual cooling. He used but little water in actual contact with the gas, believing more in the efficacy of the dry scrubbing it got in passing the divisions of the washer than in water as a cooling agent in that stage. Following these general views, he had succeeded in escaping any further trouble from naphthaline, save an occasional warning presence in his purifiers, when he accepted the hint and looked for something wrong at the back of them. When gentlemen came to understand the chemical laws governing the deposit of naphthaline, the great step to its prevention would have been taken, and it would pass out of the category of nuisances and be blessed for its useful qualities.

For the gas-engineer it seems most important to prevent the crystallisation of naphthaline, and this it appears can be done by keeping the gas containing naphthaline in contact with the light volatile oils; though all the chemical properties of naphthaline are not yet discovered, it is a well-known fact that naphthaline shows a great affinity for light hydrocarbons. In gas generated at a low temperature, many of the volatile substances are lost in an undistilled condition, with the tar in the hydraulic main and connecting pipes, in their liquid form, and combine with, or rather, take up, the naphthaline. Under an increased heat the greater part of these oils would form fixed gas, and consequently increase the volume of the gas manufactured. Though it is a great advantage to make use of as great a quantity of these lighter oils as possible in distilling the same to gas, we all know that all the lighter oils cannot be used up entirely in the distillation of cold, and thus it seems the duty of an enlightened gas-engineer not to waste the same, but to make a judicious use of it in keeping the gas as long as possible in contact with the gaseous vapours, and thus preventing the crystallisation of the naphthaline which is contained in the gas. The lighter oils, as long as they are united, will, whenever they settle down in a condensed state, carry away a great deal of naphthaline in a liquid form, and the naphthaline will, in a pipe placed in proper descent, be carried on to the drips. The lighter-oil vapours will separate from the gas at low temperature; in condensing, therefore, it is thought by many best that the take-off pipes from the hydraulic main should be nearly on a level with the same, and should be of sufficient length. Clegg gives as a rule, that for every inch of diameter, the take-off pipe should have a length of ten feet, the working pressure being two inches; for instance, the take-off pipe being ten inches in diameter, the proper length would be one hundred feet. By increased working pressure they will of course require increased length in the ratio of their square roots; but even at this rate a great deal of the lighter oils will be lost in condensation.

It had been found by experience that those oils, if collected in a little tank and re-vapourised, will greatly diminish the tendency of the naphthaline to crystallise, and at the same time improve the quality of the gas. The form of such an apparatus should be a small iron tank, closed at the top, and placed below the level of inlet pipe of the condenser, to which all drip water, and with it the lighter oils, must be conducted; the lighter oils will, from the nature of their specific gravity, float on the top of the tank. By passing a coil of steam-pipes through the tank the lighter oils will be vapourised, and the naphthaline will settle at the bottom, and from there can, from time to time, be let off. If there be an insufficient amount of these lighter oils, some benzine, benzole, or naphtha can be added with advantage, particularly if coal be used containing only a small proportion of these lighter oils. Hydrocarbon-vapours will surely liquefy naphthaline in any pipe or vessel.

A further tendency of naphthaline to crystallise will be created if gas containing naphthaline is passed in from a hot to a cold place; say, for instance, if the gas be stored in the holder, and the same, without a building, is exposed to the heat of a high temperature; when let into pipes in the ground, which are located in a lower temperature, naphthaline will surely crystallise, and in course of time will stop up the pipes more or less; or if the street mains are, in certain locations, laid too near the surface of the ground, and afterwards the gas be passed into pipes located in lower ground, by which a variation of temperature is created, naphthaline will have a tendency to crystallise.

Recently the derivatives of naphthaline, which are almost innumerable, have been receiving much attention; and many colouring-matters are produced by its reactions. These have not, however, as yet found a place, to any considerable extent, in commerce.

Naphthylin, Diamine Violet, Naphthalin Yellow (known also as Manchester Yellow and Jaune d'Or) are described in Crookes's 'Practical Handbook of Colours,' and Watts's 'Dictionary of Chemistry.' See also NAPHTHALINE DYES.

NAPHTHALIDINE. See NAPHTHYLAMINE.

NAPHTHALINE. $C^{20}H^8$ ($\mathbf{C^{10}H^8}$). A solid, crystalline hydrocarbon contained in coal-tar. It is especially interesting in consequence of its being the substance so long and perseveringly studied by Laurent. Its combinations and derivatives are immensely numerous, and, in a theoretical point of view, of the greatest importance, the well-established theory of substitutions being, to a great extent, founded upon the results obtained by treating naphthaline with nitric acid and the halogens.

NAPHTHALINE DYES. Within the last few years a number of colouring-matters, some of which are employed commercially, have been obtained from naphthylamine, itself a derivative from naphthaline. In preparing *naphthaline red*, or as it is often called, *Magdala red*, the naphthylamine is first converted into azodinaphthyldiamine, by the action of nitrous acid; and this, when treated with naphthylamine, yields a peculiar base, which forms naphthaline red. *Naphthaline blue* and *naphthaline violet* are obtained by acting on the red base with iodide of methyl, or iodide of ethyl, or by treating it with pernitrate of mercury, chloride of copper, chlorate of potash, etc. *Naphthaline yellow*, known also as *Manchester yellow*, *Martius yellow*, and *Jaune d'or*, is prepared by adding nitrite of soda to a solution of hydrochlorate of naphthylamine, when diazonaphthol is formed. On heating this with nitric acid, binitronaphthylic acid is produced, and the lime or soda compound, of this acid forms naphthaline yellow. This pigment is used for dyeing wool and silk, without the aid of a mordant, and for modifying the tint of magenta. The naphthaline dyes are fully described in Crookes's 'Practical Handbook of Colours,' and in Watts's 'Dictionary of Chemistry.'

NAPHTHYLAMINE. $C^{20}H^{9}N$ ($\mathbf{C^{10}H^{9}N}$). An organic base, isomeric with cryptidine, produced from nitronaphthaline by the action of reducing-agents, such as sulphide of ammonium, or protacetate of iron.

NAPLES YELLOW. (*Jaune minéral*, Fr.; *Neapelgelb*, Ger.) This is a fine yellow pigment prepared from antimony. It is said to be prepared by calcining about 12 parts of metallic antimony with 8 parts of red lead and 4 parts of oxide of zinc in a reverberatory furnace. The mixed oxides are to be well rubbed together and fused; after this, the fused mass is to be reduced to a very fine powder. This colour is principally prepared in Italy; but the chrome yellows have almost entirely superseded it. See YELLOW COLOURS.

NARCOTINE. $C^{44}H^{23}NO^{14}$ ($\mathbf{C^{22}H^{23}NO^{7}}$). An alkaloid contained in opium. It may be obtained in large quantities from the coloured and uncrystallisable mother-liquors obtained in the preparation of morphine by Gregory's process.

NATIVE ALLOY. A name sometimes given to OSMIUM-IRIDIUM, which see.

NATIVE METALS. See the respective metals, as COPPER, &c.

NATROLITE, from the Latin *natron*, soda. This mineral occurs reniform, botryoïdal, and massive; it has a splintery fracture; is, on the edges, translucent, and of a pearly lustre. It consists of soda, alumina, silica, and water; it is found in Scotland, Switzerland, Saxony, and Nova Scotia. Natrolite receives a high polish, and it has, therefore, been used for rings and other ornaments.

NATRON is the name of the native sesquicarbonate of soda, which occurs as a deposit on the sides of several lakes to the west of the Delta of Egypt; also as thin crusts on the surface of the earth, rarely an inch in thickness, at the bottom of a rocky mountain, in the province of Sukena, near Tripoli, and two days' journey from Fezzan, and is called by the Africans *Trona*. The walls of Cassar (Qasrr), a fort now in ruins, are said to have been built of it. At the bottom of a lake at Lagunillas, near Merida in Venezuela, is found a substance called by the Indians *Urao*, which is tolerably pure sesquicarbonate of soda. It is collected every two years by the natives, who, aided by a pole, plunge into the lake, separate the bed of earth which covers the mineral, break the urao, and rise with it to the surface of the water; it is then removed to the magazine, and dried in the sun. Natron is also found near Smyrna, in Tartary, Siberia, Hungary, Hindostan, and Mexico; in the last country there are several natron lakes, a little to the north of Zacatecas, as well as in many other provinces.

These deposits are never pure sesquicarbonate of soda, but contain generally some sulphate of soda, chloride of sodium, and earthy matters.

NATURE-PRINTING. (*Naturselbstdruck*, Ger.) The following description of this very beautiful process is an abstract of a lecture delivered by Mr. Henry Bradbury at the Royal Institution:—

Nature-printing is the name given to a technical process for obtaining printed reproductions of plants and other objects upon paper, in a manner so truthful, that only a close inspection reveals the fact of their being copies; and so distinctly sensible to even touch are the impressions, that it is difficult to persuade those unacquainted with the manipulation that they are an emanation of the printing-press.

The distinguishing feature of the process consists: first, in impressing natural objects—such as plants, mosses, seaweeds, and feathers—into plates of metal, causing, as it were, the objects to engrave themselves by pressure; secondly, in being able to take such casts or copies of the impressed plates as can be printed from at the ordinary copper-plate press.

This secures, in the case of a plant, on the one hand, a perfect representation of its characteristic outline, of some of the other external marks by which it is known, and even in some measure of its structure, as in the venation of ferns and the ribs of the leaves of flowering plants; and, on the other, affords the means of multiplying copies in a quick and easy manner, at a trifling expense compared with the result—and to an unlimited extent.

The great defect of all pictorial representations of botanical figures has consisted in the inability of art to represent faithfully those minute peculiarities by which natural objects are often best distinguished. Nature-printing has therefore come to the aid of this branch of science in particular, whilst its future development promises facilities for copying other objects of nature, the reproduction of which is not within the province of the human hand to execute; and, even if it were possible, it would involve an amount of labour scarcely commensurate with the result.

Possessing the advantages of rapid and economic production, the means of unlimited multiplication, and, above all, unsurpassable resemblance to the original, nature-printing is calculated to assist much in facilitating not only the *first-sight* recognition of many objects in natural history, but in supplying the detailed evidences of identification—which must prove of essential value to botanical science in particular.

Experiments to print direct from nature were made as far back as about 250 years; it is certain, therefore, that the present success of the art is mainly attributable to the general advance of science, and the perfection to which it has been brought in particular instances.

On account of the great expense attending the production of woodcuts of plants in early times, many naturalists suggested the possibility of making direct use of Nature herself as a copyist. In the 'Book of Art,' of Alexis Pedemontanus (printed in the year 1572), and translated into German by Wecker, may be found the *first* recorded hint as to taking impressions of plants.

At a later period, in the *Journal des Voyages*, by M. de Moncoys, in 1650, it is mentioned that one Welkenstein, a Dane, gave instruction in making impressions of plants.

The process adopted to produce such results at this period consisted in laying out flat and drying the plants. By holding them over the smoke of a candle, or an oil-lamp, they became blackened in an equal manner all over; and, by being placed between two soft leaves of paper, and being rubbed down with a smoothing-bone, the soot was imparted to the paper, and the impression of the veins and fibres was so transferred. But though the plants were dried in every case, it was by no means absolutely necessary; as the author has proved by the simple experiment of applying lamp-black or printer's ink to a fresh leaf, and producing a successful impression.

Linnæus, in his *Philosophia Botanica*, relates that in America, in 1707, impressions of plants were made by Hessel; and later (1728—1757), Professor Kniphof, at Erfurt (who refers to the experiments of Hessel), in conjunction with the bookseller Fünke, established a printing-office for the purpose. He produced a work entitled *Herbarium Vivum*. The range and extent of his work, 12 folio volumes, containing 1,200 plates, corroborates the curious fact of a printing-office being required. These impressions were obtained by the substitution of printer's ink for lamp-black, and flat pressure for the smoothing-bone; but a new feature at this time was introduced—that of colouring the impressions by hand according to nature—a proceeding which, though certainly contributing to the beauty and fidelity of the effect, yet had the disadvantage of frequently rendering indistinct, and even of sometimes totally obliterating, the tender structure and finer veins and fibres. Many persons at the time objected to the indistinctness of such representations and the absence of parts of the fructification; but it was the decided opinion of Linnæus that to obtain a representation of the difference of species was sufficient.

In 1748 Seligmann, an engraver at Nuremberg, published in folio-plates figures of several leaves he had reduced to skeletons. As he thought it impossible to make drawings sufficiently correct, he took impressions from the leaves in red ink, but no mention is made of the means he adopted. Of the greater part he gave two figures, one of the upper and another of the lower side.

In the year 1763 the process is again referred to in the *Gazette Salutaire*, in a short article upon a *Recette pour copier toutes sortes de Plantes sur Papier*.

About 25 or 30 years later, Hoppe edited his *Ectypa Plantarum Ratisbonensium*, and also his *Ectypa Plantarum Selectarum*, the illustrations in which were produced in a manner similar to that employed by Kniphof. These impressions were found also to be durable, but still were defective.

In the year 1809 mention is made in Pritzell's *Thesaurus* of a 'New Method of taking Natural Impressions of Plants'; and lastly, in reference to the early history of the subject, the attention of scientific men was called to an article, in a work published by Grazer, in 1814, on a 'New Impression of Plants.'

Twenty years afterwards the subject had undergone remarkable change, not only in the results produced, but also in the mode of operation to be pursued, which consisted in fixing an impression of the prepared plant in a plate of metal by pressure. It also appears, on the authority of Professor Thiele, that Peter Kyhl, a Danish goldsmith and engraver, established at Copenhagen, applied himself for a length of time to the ornamentation of articles in silver ware, and the means he adopted were, taking copies of flat objects of nature and art in plates of metal by means of two steel rollers. Here may be remarked the first real steps of the process from a simple contrivance to an art. The subsequent development which science has given to these means, and the amplifications which experience has added, have realised what can now be produced; but it should not be assumed that adaptation and amplification are invention.

Various productions in silver of Kyhl's process were exposed in the Exhibition of Industry held at Charlottenburg in May 1833. In a manuscript written by this Danish goldsmith, entitled 'The Description (with forty-six plates) of the Method to copy Flat Objects of Nature and Art,' dated May 1, 1833, is suggested the idea of applying this invention to the advancement of science in general. The plates accompanying this description represented printed copies of leaves, of linen and woven stuffs, of laces, of feathers of birds, scales of fishes, and even of serpent-skins.

It would appear that Peter Kyhl was no novice at the process. He distinctly points out what he conceives to be its value by the subjects that he tried to copy, and he enters into detail as to the precautions to be observed in the operation of impressing metal plates so as to insure successful impressions. His manuscript explains that he had experimented with plates of copper, zinc, tin, and lead. Still there existed obstacles which prevented him from making any application of his invention. In the case of zinc, tin, and copper plates, the plant, from the extreme hardness of the metals, was too much distorted and crushed; while in lead, though the impression was as perfect as could be, there were no means of printing many copies, as it was not possible, after the application of printer's ink, to retain the polished surface that had been imparted to the leaden plate, or to cleanse it so thoroughly as to allow the printer to take impressions free from dirty stains. This was a serious obstacle, which was not compensated for even by the peculiarly rich surface of the parts that were impressed, attributable to the lead being more granular than copper, the effect of which is so favourable to adding density or body of colour, without obliterating the veins and fibres.

Peter Kyhl died in the same year that he made known his invention. At his death his manuscripts and drawings were deposited in the archives of the Imperial Academy of Copenhagen.

To proceed to more modern efforts. Dr. Branson of Sheffield in 1847 commenced a series of experiments, an interesting paper upon which was read before the Society of Arts in 1851; and therein, for the first time, was suggested the application of that second and most important element in Nature-printing, which is now its essential feature—the Electrotype.

It then occurred to Dr. Branson that an electrotype copy would obviate the difficulty. He afterwards stated that he abandoned the process of electrotyping, in consequence of his finding it tedious, troublesome, and costly to produce large plates. Having occasion, however, to get an article cast in brass, he was astonished at the beautiful manner in which the form of the model was reproduced in the metal. He determined, therefore, to have a cast taken in brass from a gutta-percha mould of ferns, and was much gratified to see the impression rendered almost as minutely as by the electrotype process; the mode of operation is to place a frond of fern, algæ, or similar flat vegetable form, on a thick piece of glass or polished marble; by softening a piece of gutta-percha of proper size, and placing it on the leaf and pressing it carefully down, it will receive a sharp and accurate impression from the plant. The gutta-percha, allowed to harden by cooling, is then handed to a brass-cutter, who reproduces it in metal from its moulding-base.

In 1851 Professor Leydolt of the Imperial Polytechnic Institute at Vienna, availing himself of the resources of the Imperial Printing-Office, carried into execution a new method he had conceived of representing agates and other quartzose minerals in a manner true to nature. Professor Leydolt had occupied himself for a considerable period in examining the origin and composition of these interesting objects in geology. In the course of his experiments and investigations he had occasion to expose them to the action of fluoric acid, when he found, in the case of an agate, that many of the concentric rings were totally unchanged, while others, to a great extent decomposed by the acid, appeared as hollows between the unaltered bands. It then occurred to Professor Leydolt that the surfaces of bodies thus corroded might be printed from, and copies multiplied with the greatest facility.

The simplest mode for obtaining printed copies is to take an impression direct from the stone itself. The surface, after having been treated with fluoric acid, is washed with dilute hydrochloric acid and dried; then carefully blackened with printer's ink. By placing a leaf of paper upon it, and by pressing it down upon every portion of the etched or corroded surface with a burnisher, an impression is obtained, representing the crystallised rhombohedral quartz, *black*, and the weaker parts that have been decomposed by the action of the acid, *white.* It requires but a small quantity of ink, and particular care must be exercised in the rubbing down of the impression. This mode is good as far as it goes, but it is slow and uncertain, and incurs a certain amount of risk, owing to the brittle nature of the object; and the effect produced is not altogether correct, since it represents those portions black that should be white and those white that should be black.

The stone not being sufficiently strong to be subjected to the action of a printing-press, an exact *facsimile* cast, therefore, of it must be obtained, and in such a form as can be printed from. To effect this, the surface of any such stone (previously treated with fluoric acid), must be extended by embedding it in any plastic composition that will yield a flat and polished surface, so that the composition surrounding the corroded stone will be level with its surface; all that is necessary now is to prepare the whole surface for the electrotype apparatus, by which a perfect *facsimile* is produced, representing the agate impressed, as it were, into a polished plate of copper. This forms the printing-plate. The ink in this case, as opposed to the mode before referred to, is not applied upon the surface, but in the depressions caused by the action of the acid on the weaker parts; the paper is forced into these depressions in the operation of printing, which results in producing an impression in relief.

Mr. R. F. Sturges of Birmingham states that, in August 1851, he was engaged in making certain experiments with steel rollers and metal plates for ornamenting metallic surfaces, for which he obtained a patent sealed in January 1852. He produced plates in lead, tin, brass, and steel from various fabrics, such as wire-lace, thread-lace, perforated paper, and even from steel engravings, particularly a medallion of the Queen, from which impressions were printed, and which were distributed among his friends; but, that which he did led to no such result as we are at present considering, and nothing more was heard of the subject until the publication of nature-printing in its present state. He, however, also considers himself the undoubted *inventor* of nature-printing, notwithstanding what had been done by the experiment of Kyhl in 1833.

Mr. Aitken too, about this period was occupied in making experiments for the ornamentation of Britannia metal, and also claims the invention, having introduced the use of natural objects, and, as he says, expressly for printing purposes. But Sturges and Aitken only followed Kyhl in their operations, as the one experimented with steel rollers for the purpose of ornamenting metallic surfaces, while the other applied the same to printing purposes, both of which experiments were carried out by Kyhl.

In the Imperial Printing-Office at Vienna, the first application of taking impressions of lace on plates of metal, by means of rollers, took place in the month of May 1852: according to Councillor Auer's statement in his pamphlet, it originated in the Minister of the Interior, Ritter von Baumgartner, having received specimens from London, which so much attracted the attention of the Chief Director, that he determined to produce others like them. This led to the use of gutta-percha after the manner that Dr. Branson had used it; but finding this material did not possess altogether the necessary properties, the experience of Andrew Worring induced him to substitute lead, which was attended with remarkable success. This was, however, only following in the steps of Kyhl. Professor Haidinger, on seeing specimens of these laces, and learning the means by which they had been obtained, proposed the application of the process to plants.

The substitution of lead for gutta-percha was a great step in the process, but would have been insufficient had not the requisite means already existed for producing faithful copies of those delicate fibrous details that were furnished in the examples of the impressions of botanical and other figures in metal. These means consisted mainly in the great perfection to which the precipitation of metals upon moulds or matrices by electro-galvanic agency has been brought, the application of which—more generally known by the name of the Electrotype process—was suggested and executed by Dr. Branson in 1851; still he met with no signal success, which may be attributed to his experiments having been conducted on a limited scale.

The *first* practical application of nature-printing for illustrating a botanical work, and which has been attended with considerable success, is to be found in Chevalier Von Heufler's work on the mosses collected from the valley of Arpasch, in Transylvania; the *second* (*first in this country*), is a work on the 'Ferns of Great Britain and Ireland,' by Thomas Moore, published under the editorship of the late Dr. Lindley. Ferns, by their peculiar structure and general flatness, are especially adapted to develop the capabilities of the process, and there is no race of plants where minute accuracy in delineation is of more vital importance than in that of the ferns; in the distinction of which, the form of indentations, general outline, the exact manner in which repeated subdivision is effected, and especially the distribution of veins scarcely visible to the naked eye, play the most important part. To express such facts with the necessary accuracy, the art of photography would have been insufficient, until nature-printing was brought to its present state of perfection.

The beautiful productions which have been given to the public by Mr. Henry Bradbury sufficiently prove the applicability of the processes which we have described. The colouring of the plates has been greatly improved by practice; and by the deposition of nickel on the surface of the electrotype plate the printer has been enabled to print off thousands of impressions without any evidence of deterioration.

NEALING. See Annealing.

NEB-NEB is the East Indian name of Bablah. See Bablah.

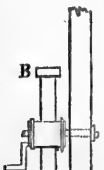
NEEDLE MANUFACTURE. When we consider the simplicity, smallness, and moderate price of a needle, we should be naturally led to suppose that this little instrument requires neither much labour nor complicated manipulations in its construction; but when we learn that every sewing needle, however inconsiderable its size, passes through the hands of 120 different operatives before it is ready for sale, we cannot fail to be surprised.

The best steel, reduced by a wire-drawing machine to the suitable diameter, is the material of which needles are formed. It is brought in bundles to the needle factory, and carefully examined. For this purpose, the ends of a few wires in each bundle are cut off, ignited, and hardened by plunging them into cold water. They are now snapped between the fingers, in order to judge of their quality; the bundles belonging to the most brittle wires are put aside, to be employed in making a peculiar kind of needle.

After the quality of the steel wire has been properly ascertained, it is calibred by means of a gauge, to see if it be equally thick and round throughout, for which purpose merely some of the coils of the bundle of wires are tried. Those that are too thick are returned to the wire-drawer, or set apart for another size of needles.

The first operation, properly speaking, of the needle factory, is unwinding the bundles of wires. With this view the operative places the coil upon a somewhat conical reel, *fig.* 1548, whereon he may fix it at a height proportioned to its diameter. The wire is wound off upon a wheel B, formed of eight equal arms, placed at equal distances round a nave, which is supported by a polished round axle of iron, made fast to a strong upright C, fixed to the floor of the workshop. Each of the arms is 54 inches long; and one of them D, consists of two parts: of an upper part, which bears the cross bar E, to which the wire is applied; and of an under part, connected with the nave. The part E slides in a slot in the fixed part F, and is made fast to it by a peg at a proper height for placing the ends of all the spokes in the circumference of a circle. This arrangement is necessary, to permit the wire to be readily taken off the reel, after being wound tight round its eight branches. The peg is then removed, the

1549



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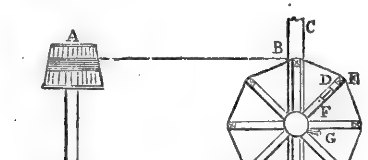

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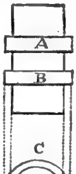
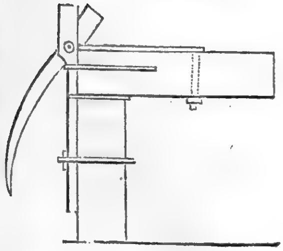
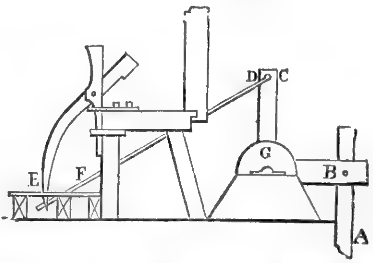


1550



1551



branch pushed down, and the coil of wire released. *Fig.* 1549 shows the wheel in profile. It is driven by the winch-handle G.

The new-made coil is cut in two points diametrically opposite, either by hand shears, of which one of the branches is fixed in a block by a bolt and a nut, as shown in *fig.* 1550, or by means of the mechanical shears, represented in *fig.* 1551. The crank A is moved by a hydraulic wheel, or by steam-power, and rises and falls alternately. The extremity of this crank enters into a mortise cut in the arm B, of a bent lever B G C, and is made fast to it by a bolt. An iron rod D F, hinged at one of its extremities to the end of the arm C, and at the other to the tail of the shears or chisel E, forces it to open and shut alternately. The operative, placed upon the floor under F, presents the coil to the action of the shears, which cut it into two bundles, composed each of 90 or 100 wires, upwards of 8 feet long. The chisel strikes 21 blows in the minute.

These bundles are afterwards cut with the same shears into the desired needle lengths, these being regulated by the diameter. For this purpose the wires are put into a semi-cylinder of the proper length, with their ends at the bottom of it and are all cut across by this gauge. The wires thus cut are deposited in a box placed alongside of the workman.

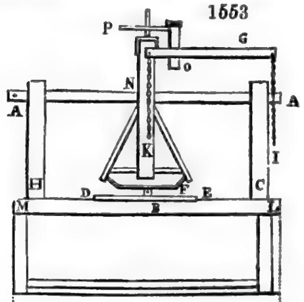
Two successive incisions are required to cut 100 wires, the third is lost; hence the shears, striking 21 blows in a minute, cut in 10 hours fully 400,000 ends of steel wire, which produce more than 800,000 needles. The wires thus cut are more or less bent, and require to be straightened. This operation is executed with great promptitude, by means of an appropriate instrument. In two strong iron rings A B, *fig.* 1552, of which one is shown in front view at C, 5,000 or 6,000 wires, closely packed together, are put; and the bundle is placed upon a flat, smooth bench L M, *fig.* 1553, covered with a cast-iron plate D E, in which there are two grooves of sufficient depth for receiving the two ring bundles of wire, or two openings like the rule F, *fig.* 1553, upon which is placed the open iron rule F, shown in front in *fig.* 1555 upon a greater scale. The two rings must be carefully set in the intervals of the rule. By making this rule come and go five or six times with such pressure upon the bundles of wires as causes it to turn upon its axis, all the wires are straightened almost instantaneously.

The construction of the machine, represented in *fig.* 1553, may require explanation. It consists of a frame in the form of a table, of which L M is the top; the cast-iron plate, D E, is inserted solidly into it. Above the table—seen in *fig.* 1554 in plan—there are two uprights, C H, to support the cross-bar, A A, which is held in forks cut out in the top of each of the two uprights. This cross-bar, A A, enters tightly into a mortise cut in the swing piece, N, at the point, N, where it is fixed by a strong pin, so that the horizontal traverse communicated to the cross-bar, A A, affects at the same time the swing-piece, N. At the bottom of this piece is fixed, as shown in the figure, the open rule, F, seen upon a larger scale in *fig.* 1555.

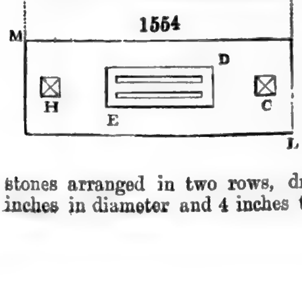
When the workman wishes to introduce the bundle, B, he raises, by means of two chains, I, K, *fig.* 1553, and the lever, G O, the swing-piece and the cross-bar. For this purpose he draws down the chain, I; and when he has placed the bundle properly, so that the two rings enter into the groove, E D, *fig.* 1553, he allows the swing-piece to fall back, so that the same rings enter the open clefts of the rule, F; he then seizes one of the projecting arms of the cross-bar, A, alternately pulling and pushing it in the horizontal direction, whereby he effects, as already stated, the straightening of the wires.

The wires are now taken to the pointing-tools, which usually consist of about 30 grindstones arranged in two rows, driven by a water-wheel. Each stone is about 18 inches in diameter and 4 inches thick. As they revolve with great velocity and are

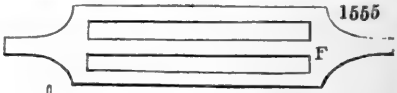
1553



1554



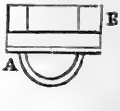
1555



1556

1557

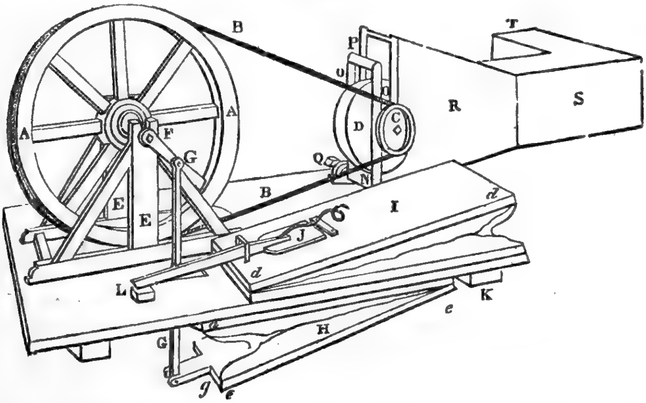
1558



liable to fly in pieces, they are partially encased by iron plates, having a proper slit in them to admit of the application of the wires. The workman seated in front of the grindstone seizes 50 or 60 wires between the thumb and forefinger of his right hand, and directs one end of the bundle to the stone. By means of a bit of stout leather called a thumb-piece, of which A, *fig.* 1558, represents the profile, and B the plan, the workman presses the wires, and turns them about with his forefinger, giving them such a rotatory motion as to make their points conical. This operation, which is called *roughing down*, is dry grinding; because, if water were made use of, the points of the needles would be rapidly rusted. It has been observed long ago that the siliceous and steel dust thrown off by the stones is injurious to the eyes and lungs of the grinders, and many methods have been proposed for preventing its bad effects. The machine invented for this purpose by Mr. Prior is one of the most effective.

A A, *fig.* 1559, is the fly-wheel of an ordinary lathe, round which the endless cord B B passes, and embraces the pulley, C, mounted upon the axle of the grindstone, D. The fly-wheel is supported by a strong frame, E E, and may be turned by a winch-handle, as usual, or by mechanical power. In the needle factories, the pointing-shops are in general very large, and contain several grindstones running on the same long horizontal shaft, placed near the floor of the apartment, and driven by water or steam-power. One of the extremities of the shaft of the wheel, A, has a kneed or bent winch, F, which by means of an intermediate crank, G G, sets in action a double bellows, H I, with a continuous blast, consisting of the air-feeder, H, below, and the air-regulator, I, above. The first is composed of two flaps, one of them, *a a*, being fast and attached to the floor, and the other, *e e*, moving with a hinge-joint; both being joined by strong leather nailed to their edges. This flap has a tail, *g*, of which the end is forked to receive the end of the crank, G. Both flaps are perforated with openings furnished with valves for the admission of the air, which is thence driven into a horizontal pipe, K, placed beneath the floor of the workshop, and may be afterwards directed in an uninterrupted blast upon the grindstone, by means of the tin tubes, N O O, which embrace it, and have longitudinal slits in them. A brass socket is supposed to be fixed upon the ground; it communicates with the pipe, K, by means of a small copper tube, into which one of the extremities of the pipe, N, is fitted; the other is supported by the point of a screw, Q, and moves round it as a pivot, so as to allow the two upright branches, O O, to be placed at the same distance from the grindstone. These branches are soldered to the horizontal pipe, N, and connected at their top by the tube, P.

1559



The wind which escapes through the slits of these pipes blows upon the grindstone, and carries off its dust into a conduit, R, *fig.* 1559, which may be extended to S, beyond the wall of the building, or bent at right angles, as at T, to receive the conduits of the other grindstones of the factory.

A safety valve, J, placed in an orifice formed in the regulator flap, I, is kept shut by a spiral spring of strong iron wire. It opens to allow the superfluous air to escape, when by the rising of the bellows, the tail, L, presses upon a small piece of wood, and thereby prevents their being injured.

The wires thus pointed at both ends are transferred to the first workshop, and cut in two, to form two needles, so that all of one quality may be of equal length. For each sort a small instrument, *fig.* 1557, is employed, being a copper-plate nearly square.

having a turned-up edge only upon two of its sides: the one of which is intended to receive all the points, and the other to resist the pressure of the shears. In this small tool a certain number of wires are put with their points in contact with the border, and they are cut together flush with the plate by means of the shears, *fig.* 1550, which are moved by the knee of the workman. The remainder of the wires are then laid upon the same copper or brass tool, and are also cut even; there being a trifling waste in this operation. The pieces of wire out of which two needles are formed are always left a little too long, as the pointer can never hit exact uniformity in his work.

These pointed wires are laid parallel to each other in little wooden boxes, and transferred to the head-flattener. This workman, seated at a table with a block of steel before him, about 3 inches cube, seizes in his left hand 20 or 25 needles, between his finger and thumb, spreading them out like a fan, with the points under the thumb, and the heads projecting; he lays these heads upon the steel block, and with a small flat-faced hammer strikes successive blows upon all the heads, so as to flatten each in an instant. He then arranges them in a box with the points turned the same way.

The flatted heads have become hardened by the blow of the hammer; when annealed, by heating and slow cooling, they are handed to the *piercer*. This is commonly a child, who laying the head upon a block of steel, and applying the point of a small punch to it, pierces the eye with a smart tap of a hammer, applied first upon one side, and then exactly opposite upon the other.

Another child trims the eyes, which he does by laying the needle upon a lump of lead, and driving a proper punch through its eye; then laying it sidewise upon a flat piece of steel, with the punch sticking in it, he gives it a tap on each side with his hammer, and causes the eye to take the shape of the punch. The operation of piercing and trimming the eyes is performed by clever children with astounding rapidity, who become so dexterous as to pierce with their punch a human hair and thread it with another, for the amusement of visitors.

The next operative makes the groove at the eye, and rounds the head. He fixes the needle in pincers, *fig.* 1556, so that the eye corresponds to their flat side: he then rests the head of the needle in an angular groove, cut in a piece of hard wood fixed in a vice, with the eye in an upright position. He now forms the groove with a single stroke of a small file, dexterously applied, first to the one side of the needle, and then to the other. He next rounds and smooths the head with a small flat file. Having finished, he opens the pincers, throws the needle upon the bench, and puts another in its place. A still more expeditious method of making the grooves and finishing the heads has been long used in most English factories. A small ram is so mounted as to be made to rise and fall by a pedal lever, so that the child works the tool with his foot, in the same way that the heads of pins are fixed. A small die of tempered steel bears the form of the one channel or groove, another similar die that of the other, both being in relief; these being worked by the lever pedal, finish the grooving of the eye at a single blow, by striking against each other with the head of the needle between them.

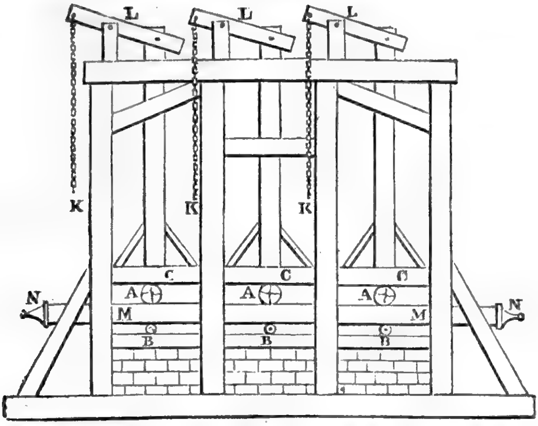
The whole of the needles thus prepared are thrown pell-mell into a sort of drawer or box, in which they are by a few dexterous jerks of the workman's hands made to arrange themselves parallel to each other.

The needles are now ready for the tempering; for which purpose they are weighed out in quantities of above 30 lbs., which contain from 250,000 to 500,000 needles, and are carried in boxes to the *temperer*. He arranges these upon sheet-iron plates, about 10 inches long and 5 inches broad, having borders only upon the two longer sides. These plates are heated in a proper furnace to bright redness for the larger needles, and to a less intense degree for the smaller; they are taken out and inverted smartly over a cistern of water, so that all the needles may be immersed at the same moment, yet distinct from another. The water being run off from the cistern, the needles are removed, and arranged by agitation in a box, as above described. Instead of heating the needles in a furnace, some manufacturers heat them by means of a bath of melted lead.

After being suddenly plunged in the cold water, they are very hard and excessively brittle. The following mode of tempering them is practised at Neustadt. The needles are thrown into a sort of frying-pan along with a quantity of grease. The pan being placed on the fire, the fatty matter soon inflames, and is allowed to burn out; the needles are now found to be sufficiently well tempered. They must, however, be re-adjusted upon the steel anvil, because many of them get twisted in the hardening and tempering.

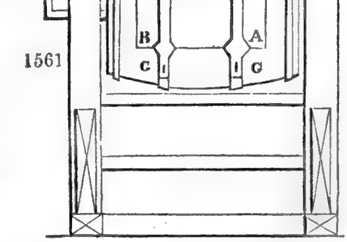
Polishing is the longest, and not the least expensive, process in the needle manufacture. This is done upon bundles containing 500,000 needles; and the same machine, under the guidance of one man, polishes from 20 to 30 bundles at a time; either by water- or steam-power. The needles are rolled up in canvas along with some quartzose sand interstratified between the layers, and this mixture is besmeared with rape-seed oil. *Fig.* 1565 represents one of the rolls or packets of needles 12 inches long, strongly bound with cords. These packets are exposed to the to-and-fro pressure of wooden tables, by which they are rolled about with the effect of causing every needle in the bundle to rub against its fellow, and against the siliceous matter, or emery, enclosed in the bag. *Fig.* 1560 represents an improved table for polishing the needles by attrition-bags. The lower table, M M, is moveable, whereas in the old construction it was fixed; the table C has merely a vertical motion, of pressure upon the bundles, whereas formerly it had both a vertical and horizontal motion. Several bundles may obviously be polished at once in the present machine. The table M M, may be of any length that is required, and from 24 to 27 inches broad; resting upon the wooden rollers, B, B, B, placed at suitable distances, it receives a horizontal motion, either by hand or other convenient power; the packets of needles A, A, A, are laid upon it, and over them the tables C, C, C, which are lifted by means of the chains K, K, K, and the levers, L, L, L, in order to allow the needles to be introduced or removed. The see-saw motion forces the *rouleaux* to turn upon their own axes, and thereby creates such attrition among their contents as to polish them. The workman has merely to distribute these rolls upon the table M, in a direction perpendicular to that in which the table moves; and whenever one of them gets displaced, he sets it right, lifting by the help of the chain the loaded table. The table makes about 20 horizontal double vibrations in the minute; whereby each bundle, running over 24 inches each time, passes through 40 feet per minute, or 800 yards in the hour.

1560



Scouring by the cask.—After being worked during 18 or 20 hours under the tables, the needles are taken out of the packets and put into wooden bowls, where they are mixed with sawdust to absorb the black grease upon their surfaces. They are next introduced into a cask, *fig.* 1561, and a workman seizing the winch P, turns it round a little; he now puts in some more sawdust at the door, A, B, which is then shut by the clasps G, G, and continues the rotation till the needles are quite clean and clear in their eyes; which he ascertains by taking out a sample of them from time to time.

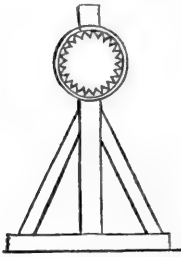
1561



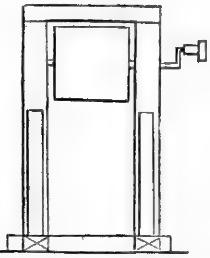
Winnowing is the next process, by means of a mechanical ventilator similar to that by which corn is winnowed. The sawdust is blown away, and the grinding powder is separated from the needles, which remain apart clean and bright.

The needles are in the next place arranged in order, by being shaken as above described, in a small, somewhat concave, iron tray. After being thus laid parallel to each other, they are shaken up against the end of the tray, and accumulated in a nearly upright position, so that they can be seized in a heap and removed in a body upon a pallet-knife, with the help of the forefinger, The preceping five operations, of making up the *rouleaux*, rolling them under the tables, scouring the needles in the cask, winnowing, and arranging them, are repeated ten times in succession, in manufacturing the best articles; the only variation being in the first process. Originally the bundles of needles are formed with alternate layers of siliceous schist and needles; but after the seventh time, bran freed from flour by sifting is substituted for the schist. The subsequent four processes, are, however, repeated as described. It has been found in England, that emery-powder mixed with quartz and mica or pounded granite, is preferable to everything else for polishing needles at first by attrition in the bags; at the second and following operations, emery mixed with olive oil is used, up to the eighth and ninth, for which putty or oxide of tin with oil is substituted for the emery; at the tenth the putty is used with very little oil; and, lastly, bran is employed to give a finish. In this mode of operating, the needles are *scoured* in the copper cask shown in elevation in *fig.* 1563, and in section in *fig.* 1562. The inner surface of this cask is studded with points to increase the friction among the needles; and a quantity of hot soap-suds is repeatedly introduced to wash them clean. The cask must be slowly turned upon its axis, for fear of injuring the mass of needles which it contains. They are finally dried in the wooden cask by attrition with sawdust; then wiped individually with a linen rag or soft leather; when the damaged ones are thrown aside.

1563



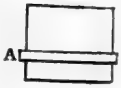
1562



1564

1565

1566



Sorting of the needles.—This operation is performed in a dry upper chamber, kept free from damp by proper stoves. Here all the points are first laid the same way; and the needles are then picked out from each other in the order of their polish. The sorting is effected with surprising facility. The workman places 2,000 or 3,000 needles in an iron ring, *fig.* 1566, 2 inches in diameter, and sets all their heads in one plane; then on looking carefully at their points, he easily recognises the broken one; and by means of a small hook fixed in a wooden handle, *fig.* 1564, he lays hold of the broken needle, and turns it out. These defective needles pass into the hands of another workman, who points them anew upon a grindstone, and they form articles of inferior value. The needles which have got bent in the polishing must now be straightened. The whole are finally arranged exactly according to their lengths by the tact of the sorter with his finger and thumb.

The needles are divided into quantities for packing in blue papers, by putting into a small balance the equivalent weight of 100 needles, and so measuring them out without the trouble of counting them individually.

The *bluer* receives these packets, and taking 25 of the needles at a time between the forefinger and thumb, he presses their points against a very small hone-stone of compact micaceous schist, mounted in a little lathe, he turns them briskly round, giving the points a bluish cast, while he polishes and improves them. This partial polish is in the direction of the axis; that of the rest of the needles is transverse, which distinguishes the boundaries of the two. The little hone-stone is not cylindrical, but quadrangular, so that it strikes successive blows with its corners upon the needles as it revolves, producing the effect of filing lengthwise. Whenever these angles seem to be blunted, they are set again by the *bluer.*

It is easy to distinguish good English needles from spurious imitations; because the former have their axes coincident with their points, which is readily observed by turning them round between the finger and thumb.

The construction of a needle requires numerous operations; but they are rapidly and uninterruptedly successive, so that a child can *trim* the eyes of 4,000 needles per hour.

NEEDLE ORE, or *Aciculite.* A native sulphide of bismuth, copper, and lead, in acicular crystals, found in Siberia. See AIKENITE.

NEPHRITE. See JADE.

NERO ANTICO. The name given by the Italians to the black marble used by the Egyptian and other ancient statuaries. See MARBLE.

NEROLI is the name given by perfumers to the essential oil of orange-flowers. It is procured by distillation with water, in the same way as most other volatile oils. Since, in distilling water from neroli, an aroma is obtained different from that of the orange-flower, it has been concluded that the distilled water of orange-flowers owes its scent to some principle different from an essential oil. See PERFUMERY.

NET (*Filet, réseau*, Fr.; *Netz*, Ger.) is a textile fabric of knotted meshes, for catching fish, and other purposes. Each mesh should be so secured as to be incapable of enlargement or diminution. The French Government offered in 1802 a prize of 10,000 francs to the person who should invent a machine for making nets upon automatic principles, and adjudged it to M. Buron, who presented his mechanical invention to the *Conservatoire des Arts et Métiers*. All the nets now used by our fishermen are made by machinery; the largest number being woven in Scotland.

NETTLE TREE. The *Celtis Australis*. The wood of the nettle-tree is nearly as compact as box, and takes a very high polish; it is sometimes used in the manufacture of flutes.

NEUTRALISATION is the state produced when acid and alkaline matters are combined in such proportions that neither predominates, as evinced by the colour of tincture of litmus and cabbage remaining unaffected by the compound.

NEUTRAL TINT. A factitious grey pigment, composed of blue, red, and yellow, in various proportions, used by water-colour painters.

NEW JERSEY TEA. The dried leaves of the *Ceanothus Americanus*.

NEW RED SANDSTONE. See SANDSTONE.

NEW ZEALAND FLAX. See PHORMIUM.

NICARAGUA WOOD. The tree yielding this wood has not been ascertained; it is supposed to be a species of *Hæmatoxylon*. This wood, and a variety called Peach wood, are sent to this country for the use of the dyers. They are similar in colour to Brazil wood; but they are not sufficiently sound for any use in manufacture.

NICKEL. The ores of nickel, found in these islands, are the following:—

Annabergite. Arsenate of nickel, found at Huel Chance and Pengelly mines in Cornwall.

Emerald nickel. Said to have been found by Dr. Heddle on chromate of iron from Swinaness, in Unst, one of the Shetland Islands.

Millerite. Sulphide of nickel. This mineral has been found in septaria, at Ebbw Vale in Monmouthshire; at Combe Martin, and at Huel Chance and Pengelly, in Cornwall.

Eisennickelkies. Sulphide of iron and nickel. On the property of the Duke of Argyll, near Inverary, this ore has been found in considerable quantities. Greg and Lettsom give the following analysis of 'a specimen of the rough ore taken and reduced to powder':—Iron, 43·76; nickel, 14·22; sulphur, 34·46; silica, 5·90; lime, 1·45: total, 99·79.

Kupfernickel. Copper nickel. Two or three mines in Cornwall have produced this ore in some quantities. It has been worked at Huel Chance and at Pengelly, and at the Fowey Consols mine. Mr. Aitkin, of Falkirk, in 1872, re-opened the so-called silver mine at Bathgate, and discovered a peculiar ore of nickel in a fissure or vein between a whinsill and the limestone; about three tons were obtained, and the work was discontinued.

Rammelsberg has given us the following analysis of a foreign kupfernickel, which corresponds very nearly with some of our English products:—Arsenic, 48·80; nickel, 39·94; cobalt, 0·16; antimony, 8·00; silica, 2·00.

For the less important and foreign ores of nickel, the reader is referred to *Dana*, or to *Brooke and Miller's Mineralogy*.

Nickel is usually associated with cobalt ores, and much chemical ingenuity has been employed to effect the perfect separation of these metals,—both of which are now very valuable in the arts. Extensive nickel refineries, in which the separation is skilfully carried out, but in all with some considerable secresy, now exist in this country. The art of working the ores of nickel and cobalt seems unknown in Great Britain, if we may judge by the fact that, though found in sufficient abundance, they are nowhere in this country converted into zaffre and speiss, the two primary marketable products elsewhere obtained from these ores. Although, therefore, no nation in the world consumes in its manufactures more cobalt and nickel than Great Britain, yet for these metals it is almost entirely dependent upon Norway, Northern Germany, and the Netherlands; from whence we import large quantities annually. The foreign ores not unfrequently yield 12 or 15 per cent. In the German ore the quantity of metallic ingredients are of a fusible character; consequently, when simply subjected to heat in a reverberatory furnace, the earthy and metallic elements separate of themselves by the mere disparity of their specific weights; and the siliceous gangue, with a portion of oxide of iron, rises to the top; leaving a metallic compound of arsenic, cobalt, nickel, copper, and perhaps iron beneath. This latter, when carefully roasted in an oxidising furnace, in contact with sand or ground flint, affords at once an impure silicate of cobalt and arsenide of nickel,—two marketable products.

Since the manufacture of German silver, or *Argentine plate*, became an object of commercial importance, the extraction of nickel has been undertaken upon a considerable scale. The cobalt ores are its most fruitful sources, and they are now generally treated by the method of Wöhler, to effect the separation of the two metals. The arsenic is expelled by roasting the powdered *speiss*, first by itself, next with the addition of charcoal-powder, till the garlic smell be no longer perceived. The residuum is to be mixed with three parts of sulphur and one of potash, melted in a crucible with a gentle heat, and the product being edulcorated with water, leaves a powder of metallic lustre, which is a sulphide of nickel free from arsenic; while the arsenic associated with the sulphur, and combining with the resulting sulphide of potassium, remains dissolved. Should any arsenic still be found in the sulphide, as may happen if the first roasting-heat was too great, the above process must be repeated. The sulphide must be finally washed, dissolved in concentrated sulphuric acid, with the addition of a little nitric; the metal is to be precipitated by a carbonated alkali, and the carbonate reduced with charcoal.

In operating upon kupfernickel, or speiss, in which nickel predominates, after the arsenic, iron, and copper, have been separated, ammonia is to be digested upon the mixed oxides of cobalt and nickel, which will dissolve them into a blue liquor. This being diluted with distilled water deprived of its air by boiling, is to be decomposed by caustic potash, till the blue colour disappears, when the whole is to be put into a bottle tightly stoppered, and set aside to settle. The green precipitate of oxide of nickel, which slowly forms, being freed by decantation from the supernatant red solution of oxide of cobalt, is to be edulcorated and reduced to the metallic state in a crucible containing crown-glass.

The reduction of the oxide of nickel with charcoal requires the heat of a powerful air-furnace or smith's-forge.

Nickel possesses a fine silver-white colour and lustre; it is hard, but malleable, both hot and cold; may be drawn into a wire $\frac{1}{50}$th of an inch, and rolled into plates $\frac{1}{500}$th of an inch thick. A small quantity of arsenic destroys its ductility. When fused it has a specific gravity of 8·279, and, when hammered, of 8·66 or 8·82; it is susceptible of magnetism, in a somewhat inferior degree to iron, but superior to cobalt. Its melting-point is nearly as high as that of manganese. It is not oxidised by contact of air, but may be burned in oxygen gas.

There is one oxide and a sesquioxide of nickel. The oxide is of an ash-grey colour, and is obtained by precipitation with an alkali from the solution of the chlo ide or nitrate. The sesquioxide is black, and may be procured by exposing the nitrate to a heat under redness. The hydrated oxide has a dirty pale-green colour.

ANALYSIS OF NICKEL.

Nickel may be detected by cyanide of potassium in an acid solution of it and cobalt; the cyanide being added until the precipitate first formed is redissolved: dilute sulphuric acid is then added, and the mixture warmed and allowed to stand. A precipitate appearing shows the presence of nickel, whether it be cobalt-cyanide or simple cyanide of nickel.

Nickel and cobalt are almost always associated together, and are very difficult to separate.

Upon the fact that in a solution of oxide of cobalt containing free hydrochloric acid the whole of the metal is converted into the super-oxide, by means of chlorine, while the chloride of nickel remains unaltered in the acid solution, H. Rose based a successful method for the separation of the metals. His method is as follows:—

Both metals are dissolved in hydrochloric acid; the solution must contain a sufficient excess of free acid; it is then diluted with much water; if 1 or 2 grammes of the oxides are operated on, about 2 lbs. of water are added to the solution. As cobalt possesses a much greater colouring-power than nickel, not only in fluxes, but also in solutions, the diluted solution is of a rose colour, even when the quantity of nickel present greatly exceeds that of the cobalt. A current of chlorine gas is then passed through the solution for several hours: the fluid must be thoroughly saturated with it, and the upper part of the flask above the liquid must remain filled with the gas after the current has ceased. Carbonate of baryta in excess is then added, and the whole allowed to stand for 12 or 18 hours, and frequently agitated. The precipitated superoxide of cobalt, and the excess of carbonate of baryta, are well washed with cold water, and dissolved in hot hydrochloric acid; after the separation of the baryta by sulphuric acid, the cobalt is precipitated by hydrate of potash, and, after being washed and dried, is reduced in a platinum or porcelain crucible by hydrogen gas. The fluid filtered from the superoxide of cobalt is of a pure green colour. It is free from any trace of cobalt. After the removal of the baryta by means of sulphuric acid, the oxide of nickel is precipitated by caustic potash. Even this method did not give exact results on the first trial. 0·318 gr. metallic nickel and 0·603 gr. metallic cobalt were employed, and 0·430 gr. oxide of nickel and 0·580 gr. cobalt were obtained:

	Employed	Obtained
Nickel	34·53	36·75
Cobalt	65·47	62·98
	100·00	99·73

The cause of these incorrect results is, that the solution was filtered an hour or two after the precipitation of the superoxide of cobalt by the carbonate of baryta. It is necessary, however, to wait a considerable time, at least 12 hours, or even 18 is better, and allow the excess of carbonate of baryta to remain in contact with the solution, as the superoxide of cobalt is precipitated very slowly: this explains the diminution of the cobalt and increase of the nickel in the above experiment.

It will be readily perceived that not only cobalt, but also other metals, as iron and manganese, may be separated from nickel by this method. On the other hand, oxide of cobalt may be separated from the oxide of zinc, and other strongly basic oxides, which are not converted into superoxides. Nickel and cobalt can, moreover, be separated from metals to which they bear a close analogy in various ways.

From nickel, manganese may be best separated in the same manner as cobalt. Manganese may be separated from both of them, however, by a method which, in its essential parts, was proposed by Wackenroder. It is based upon the fact that, although nickel and cobalt are not precipitated from their solutions by sulphuretted hydrogen, especially when they are slightly acid, still the sulphides precipitated by hydrosulphate of ammonia are not dissolved by very dilute hydrochloric acid. When the oxides are contained in an acid solution (which should not contain nitric acid, however), it is made ammoniacal, and they are precipitated as sulphurets by hydrosulphate of ammonia. Very dilute hydrochloric acid is then added to the solution, until it has a very slight acid reaction; the sulphides of nickel and cobalt remain undissolved; they are washed with water containing a little sulphuretted hydrogen and a trace of hydrochloric acid. The sulphide of manganese is dissolved with facility, but, although the fluid filtered from the sulphides of nickel and cobalt gives only a rather dirty flesh-coloured precipitate on the addition of ammonia and hydrosulphate of ammonia, still the sulphide of manganese contains small portions of sulphide of cobalt or nickel; and when, therefore, it is treated anew with very dilute hydrochloric acid, minute quantities of the black sulphides remain behind. By this repeated treatment a very nearly correct separation may be obtained; but the results are more satisfactory in the separation of cobalt from manganese than of nickel from the latter metal, evidently because nickel is not very perfectly precipitated by hydrosulphate of ammonia: 0·303 gr. of metallic cobalt and 0·385 gr. of binoxide of manganese gave—after the sulphide had been converted by *aqua regia* into oxide, and this precipitated by hydrate of potash, and after the chloride of manganese dissolved was free from sulphuretted hydrogen and precipitated by carbonate of soda—0·302 metallic cobalt and 0·392 oxide of manganese.

0·251 gr. of oxide of nickel and 0·296 gr. oxide of manganese, treated in the same manner, gave 0·214 oxide of nickel and 0·324 oxide of manganese.

Iron also may be separated from nickel, and better still from cobalt, in the same manner as manganese, since sulphide of iron, like sulphide of manganese, is easily soluble in very dilute hydrochloric acid; but in this case the resolution of the sulphide of iron is likewise necessary: 0·425 gr. metallic cobalt and 0·170 gr. sesquioxide of iron, when treated in this manner, gave 0·414 gr. metallic cobalt and 0·172 gr. sesquioxide of iron.

For the details of processes which have been found useful in the separation of nickel from other bodies, the reader is referred to Watts's 'Dictionary of Chemistry.'

Alloys of Nickel.—Various alloys of nickel have been formed under different names; the following are a few of them:—

Argentane, or *German Silver*, consists of 8 parts of copper, 2 parts of nickel, and 3 parts of zinc. This composition has often a yellow tinge, and it is consequently employed for inferior articles only. Another formula gives copper 50·000, zinc 25·0, and nickel 25·0.

White Argentane, or *Argentine Plate*, is usually copper 8 parts, nickel 3 parts, zinc 3 parts. This is a very fine alloy, and passes under different names, according to the caprice of the manufacturer. A manufacturer's receipt which we have seen is: copper 60·0, zinc 17·0, nickel 23·5.

Electrum, copper 8 parts, nickel 4 parts, and zinc 3 parts. This composition has many advantages, especially in its fine colour, and its resistance of oxidation.

Copper 8 parts, nickel 6 parts, and zinc 3 parts, is a very hard and fine compound-metal; but from its hardness there is some difficulty in working it.

Tutenague of China—*Packfong* of the East Indies—is copper 8 parts, nickel 3 parts, and zinc 3½ parts.

A solder for German silver is prepared by fusing together 4 parts of the ordinary argentine and 5 parts of zinc.

Nickel may, it appears, be alloyed with iron. Stromeyer describes a native compound of this kind; and Berthier states that, by heating the arsenide of nickel with iron in any proportions, double arsenides are obtained, which are hard and brittle, with a cast-iron colour.

The process of nickel-plating, now extensively practised, is described under ELECTRO-METALLURGY.

NICOTIANA TABACUM. The tobacco plant; so called in honour of John Nicot of Nismes, ambassador from the King of France to Portugal, who procured the first seeds from a Dutchman, who obtained them from Florida. See TOBACCO.

NICOTIANINE. This is a concrete volatile oil, obtained by distilling tobacco-leaves with water; a turbid liquid comes over, and, after standing some time, this oil forms on the surface; only a very small quantity is produced, 6 lbs. of the leaves yield only 11 grains. This oil is solid, has the odour of tobacco, and a bitter taste. It is volatile, insoluble in water and the dilute acids, and in alcohol and ether, but soluble in caustic potash. It has a resemblance to camphor, and was called by Gmelin 'Tobacco Camphor.'

NICOTINE. This alkaloïd is the active principle of the tobacco-plant; it was first obtained, in an impure state, by Vauquelin in 1809. It is contained in the different species of tobacco, probably in the state of malate or citrate. It was obtained pure by Possel and Reimann from the leaves of the *Nicotiana tabacum*, *Macrophylla rustica*, and *M. glutinosa*. Nicotine and its salts have been examined and analysed by MM. Ortigasa, Barral, Melsens, and Schlösing.

The following is the process employed by M. Schlösing for extracting the nicotine from the tobacco:—

The tobacco-leaves are exhausted by boiling-water; the extract is then evaporated till solid, or to a syrupy consistence, and shaken with twice its volume of alcohol. Two layers are formed; the under layer is black and almost solid, and contains some malate of lime, the upper layer containing all the nicotine. This latter is concentrated by distillation, and again treated with alcohol to precipitate certain substances. This solution is concentrated, and treated with a concentrated solution of potash; it is allowed to cool, and is then agitated with ether, which dissolves all the nicotine. To the ethereal solution is added powdered oxalic acid, when oxalate of nicotine is precipitated as a syrupy mass. This is washed with ether, treated with potash, taken up with water, and distilled in a salt-bath, when the nicotine comes over, and may be rendered pure and colourless by redistilling in a current of hydrogen.

M. Melsens has observed the presence of nicotine in the condensed products of tobacco-smoke. The oil which is formed in pipes after smoking tobacco in them, and which gives the colour to the pipe, contains nicotine. The question may then perhaps be asked, 'If tobacco-smoke contains such a deadly poison, why are there not more ill effects from smoking?' It may perhaps be answered in this way: tobacco when smoked only yields about $\frac{1}{150}$th or less of its weight of nicotine, and then very little of that is condensed in the mouth. And, again, the system may become accustomed to it, as is the case with opium-eaters, and *then* it requires much more to take an effect; it can scarcely be doubted, though, that the continual habit of smoking large quantities of tobacco is injurious.

Nicotine when pure is a colourless, transparent, oily liquid, possessing an acrid odour and an acrid burning taste. Its density is 1·024, and that of its vapour 5·607. It restores the blue colour of reddened litmus, and renders turmeric brown. It becomes yellowish by age, and when exposed to the air becomes brown and thick, absorbing oxygen. It is very soluble in water, alcohol, and the oils (fixed and volatile); also in ether, which has the power of extracting it completely from its aqueous solution.

It is very hygrometrical; exposed to a moist atmosphere it rapidly absorbs water, but loses it again in an atmosphere dried by potash. When thus hydrated it becomes a solid crystalline mass if exposed to the cold of a mixture of ice and salt. When anhydrous it does not become solid at 14° Fahr. It boils at 482° Fahr. and is at the same time slightly decomposed; but notwithstanding its high boiling-point, it may be easily distilled with the vapour of water without decomposition.

The vapour of nicotine is so irritating, that we should experience a difficulty of breathing in a room where a drop of that alkaloïd had been volatilised. Its vapour burns with a white smoky flame, depositing charcoal, like an essential oil. Nicotine turns the plane of polarisation strongly to the left. From the volume of its vapour, and from the quantity of sulphuric acid required to form with it a neutral salt, the formula of nicotine would appear to be $C^{20}H^{14}N^{2}$ ($\mathbf{C^{10}H^{14}N^{2}}$); but from some of its combinations it would appear to be half of this, viz. $C^{10}H^{7}N$.

By the aid of heat nicotine dissolves sulphur, but not phosphorus. Nicotine unites with acids, forming salts, which are very deliquescent, difficultly crystallisable, insoluble in ether, except the acetate, and when pure possess no smell, but an acrid tobacco taste. The double salts which nicotine forms crystallise much more easily.

The aqueous solution of nicotine is colourless, transparent, and strongly alkaline; it forms a white precipitate in a solution of corrosive sublimate, also in a solution of acetate of lead, and with both chlorides of tin. The precipitate which it forms with solutions of the salts of zinc is soluble in an excess of nicotine. Salts of copper give with it, at first, blue precipitates, but these dissolve in excess of nicotine, forming a deep blue solution, as they do when supersaturated with ammonia. Bichloride of platinum yields with it a yellow granular precipitate. A solution of permanganate of potash is immediately decolourised by a solution of nicotine.

NIELLO (Ital.). *Nigellum.* An art to which we owe the origin of engraving. It consisted in drawing a design with a style upon gold and silver, and then cutting it with a burin; a black composition made by heating together copper, silver, lead, and sulphur, which when cold was pounded, was then laid upon an engraved plate, a little borax sprinkled over it, and placed over a charcoal fire, when the composition dissolved and flowed into the lines of the design. When cold, the metal was scraped and burnished, and the niello presented the effect of a drawing in black upon gold or silver. The art was known to the ancients and practised during the middle ages; specimens, though rare are to be met with in museums. In the fifteenth century these designs were frequently engraved with great delicacy, and the shadows *hatched* with lines, precisely like a copper-plate engraving. The origin of taking paper impressions from metal plates is ascribed to the practice of Maso Finiguerra, a Florentine goldsmith, who, in the middle of the fifteenth century, was in the habit of taking impressions of his incised work on cups and plaques in a viscid water-ink on paper, for the purpose of testing the state of his work. Such impressions of the early fathers of copper-plate printing still exist, and are known also as *niellos*. See Sulphurs.

NIOBIUM. A metal discovered in 1801 by Hatchett in a mineral called *columbite*, and hence it was named *columbium.* Rose rediscovered this metal in 1846, and gave it the name it now bears. Niobium is a black powder; specific gravity 6·27. See Watts's 'Dictionary of Chemistry.'

NITRATES OF AMMONIA, LEAD, POTASH, SILVER, SODA, STRONTIA. The salts of nitric acid which are employed in the arts are described under the heads of the metallic or earth constituent.

NITRE. The common name for Nitrate of Potash. See Potash, Nitrate of.

NITRE, CUBIC. Nitrate of soda. See Cubic Nitre and Soda, Nitrate of. Our *Imports* of cubic nitre have been as follow:—

	1872		1873	
	Tons	Value	Tons	Value
From Peru . . .	1,365,195	£1,045,383	2,176,239	£1,604,040
Bolivia . .	156,870	120,475	145,371	105,492
Chili . .	55,966	42,451	85,260	57,173
Other countries	16,166	12,122	537	426
Total . . .	1,594,197	£1,220,411	2,407,407	£1,767,131

NITRIC ACID, *Aquafortis* (*Acide nitrique*, Fr.; *Salpetersäure*, Ger.), exists, in combination with the bases, potash, soda, lime, and magnesia, in both the mineral and vegetable kingdoms. This acid is never found insulated. It was distilled from saltpetre so long ago as the thirteenth century, by igniting that salt mixed with copperas or clay, in a retort. Nitric acid is generated when a mixture of oxygen and nitrogen gases, confined over water or an alkaline solution, has a series of electrical explosions passed through it. In this way the salubrious atmosphere may be converted into corrosive aquafortis. When a little hydrogen is introduced into the mixed gases, standing over water, the chemical agency of the electricity becomes more intense, and the acid is more rapidly formed from its elements, with the production of some nitrate of ammonia. The formula of the hydrated acid is HO,NO^5 (**HNO^3**); its equivalent being 54.

Nitric acid is usually made on the small scale by distilling, with the heat of a sand-bath, a mixture of 3 parts of pure nitre, and 2 parts of strong sulphuric acid, in a large glass retort, connected by a long glass tube with a globular receiver surrounded by cold water. By a well-regulated distillation, a pure acid, of specific gravity 1·500 may be thus obtained, amounting in weight to about two-thirds of the nitre employed. To obtain the whole nitric acid equal weights of nitre and concentrated sulphuric acid may be taken; in which case but a moderate heat need be applied to the retort. The residuum will be bisulphate of potash. When only the single equivalent proportion of sulphuric acid is used, namely 48 parts for 100 of nitre, a much higher heat is required to complete the distillation, whereby more or less of the nitric acid is decomposed, while a compact neutral sulphate of potash is left in the retort, very difficult to remove by solution in water, and therefore apt to destroy the vessel.

Aquafortis is manufactured upon the great scale in iron pots or cylinders of the same construction as are described under Hydrochloric Acid. The more concentrated the sulphuric acid is, the less corrosively will it act upon the metal: and it is commonly used in the proportion of one part by weight to two of nitre.

Commercial aquafortis is very generally contaminated with sulphuric and muriatic acids, as also with alkaline sulphates and muriates. The quantity of these salts may be readily ascertained by evaporating in a glass capsule a given weight of the aquafortis; while that of the muriatic acid may be determined by nitrate of silver; and of sulphuric acid, by nitrate of baryta. Aquafortis may be purified, in a great measure, by redistillation at a gentle heat; rejecting the first liquid which comes over, as it contains the chlorine impregnation; receiving the middle portion as genuine nitric acid; and leaving a residuum in the retort, as being contaminated with sulphuric acid.

Since nitrate of soda has been so abundantly imported into Europe from Peru, it has been employed by many manufacturers in preference to nitre for the extraction of nitric acid, because it is cheaper, and because the residuum of the distillation, being sulphate

A Table of Nitric Acid, by Dr. Ure.

Specific gravity	Liq. acid in 100	Dry acid in 100	Specific gravity	Liq. acid in 100	Dry acid in 100	Specific gravity	Liq. acid in 100	Dry acid in 100	Specific gravity	Liq. acid in 100	Dry acid in 100
1·5000	100	79·700	1·4189	75	59·775	1·2947	50	39·850	1·1403	25	19·925
1·4980	99	78·903	1·4147	74	58·978	1·2827	49	39·053	1·1345	24	19·128
1·4960	98	78·106	1·4107	73	58·181	1·2826	48	38·256	1·1286	23	18·331
1·4940	97	77·309	1·4065	72	57·384	1·2765	47	37·459	1·1227	22	17·534
1·4910	96	76·512	1·4023	71	56·587	1·2705	46	36·662	1·1168	21	16·737
1·4880	95	75·715	1·3978	70	55·790	1·2644	45	35·865	1·1109	20	15·940
1·4850	94	74·918	1·3945	69	54·993	1·2583	44	35·068	1·1051	19	15·143
1·4820	93	74·121	1·3882	68	54·196	1·2523	43	34·271	1·0993	18	14·346
1·4790	92	73·324	1·3833	67	53·399	1·2462	42	33·474	1·0935	17	13·549
1·4760	91	72·527	1·3783	66	52·602	1·2402	41	32·677	1·0878	16	12·752
1·4730	90	71·730	1·3732	65	51·805	1·2341	40	31·880	1·0821	15	11·955
1·4700	89	70·933	1·3681	64	51·068	1·2277	39	31·083	1·0764	14	11·158
1·4670	88	70·136	1·3630	63	50·211	1·2212	38	30·286	1·0708	13	10·361
1·4640	87	69·339	1·3579	62	49·414	1·2148	37	29·489	1·0651	12	9·564
1·4600	86	68·542	1·3529	61	48·617	1·2084	36	28·692	1·0595	11	8·767
1·4570	85	67·745	1·3477	60	47·820	1·2019	35	27·895	1·0540	10	7·970
1·4530	84	66·948	1·3427	59	47·023	1·1958	34	27·098	1·0485	9	7·173
1·4500	83	66·155	1·3376	58	46·226	1·1895	33	26·301	1·0430	8	6·376
1·4460	82	65·354	1·3323	57	45·429	1·1833	32	25·504	1·0375	7	5·579
1·4424	81	64·557	1·3270	56	44·632	1·1770	31	24·707	1·0320	6	4·782
1·4385	80	63·760	1·3216	55	43·835	1·1709	30	23·900	1·0267	5	3·985
1·4346	79	62·963	1·3163	54	43·038	1·1648	29	23·113	1·0212	4	3·188
1·4306	78	62·166	1·3110	53	42·241	1·1587	28	22·316	1·0159	3	2·391
1·4269	77	61·369	1·3056	52	41·444	1·1515	27	21·519	1·0106	2	1·594
1·4228	76	60·572	1·3001	51	40·647	1·1465	26	20·722	1·0053	1	0·797

of soda, is more readily removed by solution from glass retorts, when a range of these set in a gallery furnace is the apparatus employed. Nitric acid of specific gravity 1·47 may be obtained colourless; but by further concentration a portion of it is decomposed, whereby some nitrous acid is produced, which gives it a straw-yellow tinge. At this strength it exhales white or orange fumes, which have a peculiar, though not very disagreeable smell; and even when largely diluted with water it tastes extremely sour. The greatest density at which it can be obtained is 1·51 or perhaps 1·52, at 60° Fahr., in which state, or even when much weaker, it powerfully corrodes all animal, vegetable, and most metallic bodies. When slightly diluted, it is applied, with many precautions, to silk and woollen stuffs, to stain them of a bright yellow hue.

In the anhydrous state, this body consists of 26·15 parts by weight of nitrogen, and 73·85 of oxygen; or of 2 volumes of the first gas and 5 volumes of the second.

When of specific gravity 1·5, the acid boils at about 210° Fahr.; of 1·45, it boils at about 240°; of 1·42, it boils at 253°; and of 1·40, at 246° F. If an acid stronger than 1·420 be distilled in a retort, it gradually becomes weaker; and if weaker than 1·42, it gradually becomes stronger, till it assumes that standard density. Acid of specific gravity 1·485 has no more action upon tin than water has, though when either stronger or weaker it oxidises it rapidly, and evolves fumes of nitrous gas with explosive violence. In two papers upon nitric acid, published by Dr. Ure in the fourth and sixth volumes of the 'Journal of Science' (1818 and 1819), he investigated the chemical relations of these phenomena. Acid of 1·420 consists of 1 atom of dry acid and 4 of water; acid of 1·485, of 1 atom of dry acid and 2 of water; the latter compound possesses a stable equilibrium as to chemical agency; the former as to calorific. Acid of specific gravity 1·334, consisting of 7 atoms of water and 1 of dry acid, resists the decomposing agency of light. Nitric acid acts with great energy upon most combustible substances, simple or compound, giving up oxygen to them, and resolving itself into nitrous gas, or even nitrogen. Such is the result of its action upon hydrogen, phosphorus, sulphur, charcoal, sugar, gum, starch, silver, mercury, copper, iron, tin, and most other metals.

Nitric acid is never obtained as the waste product of any chemical operation. Its manufacture is invariably the primary object of the process by which it is procured.

It has been proposed to decompose nitrate of soda by the action of boracic acid, so as to produce biborate of soda, or borax, and thus render the nitric acid a secondary product. The success of this process depends, however, upon a circumstance of a somewhat curious kind. Strong nitric acid is much more volatile than weak acid; and hence it is more easily expelled from its combination with soda in a concentrated than in a diluted form. Now, boracic acid has 3 atoms of water in its crystallised condition; therefore, if we take 2 atoms of this acid, we have 6 atoms of water to unite with the 1 atom of nitric acid capable of being disengaged from nitrate of soda; whereas this quantity of nitric acid needs at most but 2 atoms. The secret, therefore, is to dry the boracic acid in the first instance, so as to get rid of the surplus water; and this is easily done at a temperature of 212° Fahr., at which two-thirds of the water readily leave the boracic acid, and thus afford a mono-hydrated compound, 2 atoms of which contain precisely the amount of water needed for 1 atom of nitric acid, and also of the boracic acid requisite for the production of the biborate of soda. There are some peculiarities connected with the application of the necessary temperature, but they are of less importance. The biborate of soda is afterwards dissolved in hot water, and crystallised.

Anhydrous nitric acid, known to modern chemists as *nitric anhydride, nitric oxide*, or *nitrogen pentoxide*, was discovered in 1849 by M. Deville, who isolated it by the action of dry chlorine gas on nitrate of silver, heated at first to about 200° Fahr., and then reduced in temperature to about 150°. The anhydride, or radical of the acid, is expelled, and condenses in transparent, brilliant, colourless crystals, which are extremely unstable, and readily dissolve in water, with production of ordinary nitric acid.

NITRITES. Salts formed by the combination of nitrous acid with the metals, earths, or alkalis. See Watts's 'Dictionary of Chemistry.'

NITROBENZOL. *Azobenzol.* $C^{12}H^5(NO^4)$ [$\mathbf{C^6H^5(NO^2)}$]. It is important in the arts, both as a source of aniline for the manufacture of dye-colours, and on account of its use for flavouring, as a substitute for oil of bitter almonds, which it closely resembles in flavour when pure, and over which it has the advantage of not being poisonous.

It is prepared from benzol (which see) by adding it, drop by drop, into hot, fuming nitric acid; the nitrobenzol separates on dilution with water in the form of a yellowish oil, which may be purified by washing with water alone, or a solution of carbonate of soda. It has a density of 1·209 at 60° Fahr. (15·5 Cent.), and just above the freezing-point of water is converted into a crystalline solid. It is nearly insoluble in water; but alcohol and ether dissolve it in all proportions. Its conversion into aniline under the influence of reducing-agents has been before mentioned. See ANILINE.

Nitrobenzol may be viewed as having been derived from benzol, $C^{12}H^6$ ($\mathbf{C^6H^6}$), by the substitution of one equivalent of hydrogen by the tetroxide of nitrogen.

NITROGEN. *Symbol*, N; *equivalent*, 14; *combining-measure*, two volumes; *specific gravity*, 0·9713; *Syn.* Azote. (*Nitrogène, Azote*, Fr.; *Stickstoff, Salpeterstoff*, Ger.) This gas, which serves so important a purpose in diluting the atmospheric oxygen to the point necessary for healthy respiration, has been known, in a more or less impure state, since 1772, when Dr. Rutherford showed that the vitiated air from the lungs contained a principle incapable of supporting life, but differing from carbonic acid.

Preparation.—Nitrogen is usually prepared from atmospheric air by removing its oxygen. This may be done in a variety of ways:—1. By burning some substance in a confined portion of air, and removing the oxide by a solvent. Thus, alcohol burnt in air yields nitrogen, water, and carbonic acid, The water condenses, and the carbonic acid may be absorbed by agitation with lime-water. The oxygen may also be taken away by the combustion of phosphorus. The phosphoric acid produced, being soluble in water, is easily removed. 2. The most elegant mode of obtaining the nitrogen, and one which, properly performed, is susceptible of the highest quantitative accuracy, is to pass air over red-hot copper, which absorbs the oxygen, forming oxide of copper, pure nitrogen remaining. 3. The oxygen of atmospheric air may also be removed by certain solvents. A solution of pyrogallate of potash, or, rather a solution of pyrogallic acid in an excess of potash, takes the oxygen from air with great rapidity and great precision. Upon this fact Liebig founded his process for estimating the percentage of oxygen in certain gaseous mixtures. A very pure nitrogen may be obtained, according to Corenwinder, by heating a solution of nitrate of potash with chloride of ammonium. Nitrogen may be obtained from ammonia by the action of chlorine, which combines with the hydrogen. Flesh gently heated with diluted nitric acid yields the gas, contaminated with its binoxide. The latter may conveniently be got rid of by passing the gases liberated through two Liebig's potash-bulbs filled with a moderately-concentrated solution of protosulphate of iron.

Properties.—Nitrogen has, especially until lately, been regarded as one of the most inert of the elements, as a body with but slight tendency to enter into combination, and, when combined, being easily removed by even the least energetic reaction. This opinion has been founded on too limited a study of its properties. It is true that with some elements it unites but feebly, and such combinations are, in a few cases, decomposed by the slightest causes; and, in the case of the so-called iodide and chloride, by mere friction or percussion. But the energies of nitrogen are not to be estimated from these compounds alone. There are bodies with which it exhibits an intense desire for union; among these may be mentioned carbon, titanium, and boron. Hydrogen and certain organic groups also unite readily with nitrogen, forming stable and highly characteristic classes of compounds.

Determination of the Purity of Nitrogen Gas.—The simplest and most accurate process is that of M. Bunsen. The first thing is to determine whether a combustible gas containing oxygen be present. For this purpose it is merely necessary to pass an electric spark through the gas contained in a eudiometer. If the bulk remains unaltered the absence of any considerable amount of combustible gas mixing with oxygen is proved. But they may be present in such small quantity, as compared with the noncombustible gas, that no explosion can ensue on passing the spark. It is then necessary to add some battery-gas in order to render the mixture inflammable. [By 'battery-gas' is understood the gas obtained by the electrolysis of water.] For the purpose of the experiment, we may add to every 100 volumes of the gas under examination 40 volumes of battery-gas. If the volume after explosion be unaltered, the total absence of oxygen and combustible gases is demonstrated. It is still possible that the nitrogen may be contaminated with oxygen, although inflammable gases are absent. To determine this fact we must add both hydrogen and battery-gas in such proportions that the volume of the original gas plus hydrogen is to that of the battery gas as 100 : 40. If no oxygen be present the volume after explosion will be that of the original gas and the hydrogen; the reason being that if oxygen had been present some of the hydrogen would have disappeared in order to form water. The nitrogen gas may still be contaminated by a trace of a combustible gas. To determine this point as much common air is to be added to the last mixture containing hydrogen as will form a detonating mixture with that hydrogen. This detonating mixture so produced should form from 26 to 64 per cent. of the incombustible gases. If, on making the explosion, it is found that two-thirds of the condensation is equal to the volume of the hydrogen added, it will show that no combustible gas was present, and that, therefore, the original gas consisted of pure nitrogen.

Compounds of Nitrogen with Oxygen.—The following table contains the composition and principal physical properties of the oxides of nitrogen:—

Table of the Composition and Physical Properties of the Oxides of Nitrogen.

Name	Formulæ		Specific gravity of gas	Combining vol.	Atomic weight	Weight of 100 c. inches of gas or vapour
Protoxide of nitrogen, *syn.* nitrous oxide or laughing gas . .	NO	$\mathbf{N^2O}$	1·527	Two volumes	22·	46·3 grains
Binoxide of nitrogen, *syn.* nitric oxide .	NO^2	$\mathbf{N^2O^2}$	1·039	„	30·	32·2 „
Nitrous acid, *syn.* hyponitrous acid .	NO^3	$\mathbf{N^2O^3}$	2·630	„	38·	81·5 „
Peroxide of nitrogen, *syn.* hyponitric acid	NO^4	$\mathbf{N^2O^4}$	1·720	„	46·	53·3 „
Nitric acid . .	$NO^5.HO$ or NO^6H	$\mathbf{NO^3H}$	...	...	63·	...

In the above table the densities of the vapours of nitrous and nitric acids are given as obtained by calculation on the hypothesis that they could exist at 60° and 30 inches without condensation; that is to say, as the numbers would come out in a determination of the vapour-density by the method by M. Dumas.

Special Affinities of Nitrogen.—In the same manner that ordinary metallic substances absorb oxygen with avidity from the atmosphere, especially at more or less elevated temperatures, so other elementary bodies combine with nitrogen to form the nitrides. Messrs. Wöhler and Sainte-Claire Deville have carefully investigated this subject, and with great success. When a mixture of titanic acid and charcoal is heated in a charcoal tray (contained in a charcoal tube) to a temperature sufficient to fuse platinum, and a current of dry nitrogen is sent over the mixture, the gas is absorbed with such rapidity that, no matter how rapid the current, none escapes from the tube.

Boron also possesses great tendency to combine with nitrogen at high temperatures. Amorphous boron heated in a current of ammonia becomes incandescent; the nitrogen is absorbed, and the hydrogen escapes, and may be inflamed at the exit of the apparatus. A mixture of boracic acid and charcoal, if ignited in a current of nitrogen, yields the white infusible nitride of boron, first described by Mr. Balmain under the name of Æthogen, but subsequently more accurately investigated by M. Wöhler.

Silicon also combines with nitrogen under favourable circumstances. These facts, coupled with the old experiment made by the French chemists on the nitride of potassium, and the action of ammonia at a red heat upon iron, show that nitrogen is far from being the inert substance generally supposed.—C. G. W.

NITROGEN, BINOXIDE OF; *Nitrogen dioxide,* or *Nitric oxide* (*Deutoxide d'azote,* Fr.; *Stickstoffoxyd,* Ger.), NO^2 ($\mathbf{N^2O^2}$), is a gaseous body which may be obtained by pouring upon copper or mercury, in a retort, nitric acid of moderate strength. The nitrous gas comes over in abundance without the aid of heat, and may be received over water freed from air, or over mercury, in the pneumatic trough. It is elastic and colourless; what taste and smell it possesses are unknown, because the moment it is exposed to the mouth or nostrils, it absorbs atmospherical oxygen, and becomes nitrous or nitric acid. Its specific gravity is 1·0393, or 1·04; whence 100 cubic inches weigh 36·66 gr. Water condenses not more than $\frac{1}{20}$th of its volume of this gas. It extinguishes animal life, and the flame of many combustibles; but of phosphorus, well kindled, it brightens the flame in a remarkable degree. A mixture of nitric acid and bisulphide of carbon burns with a flame of high actinic power, and may be used in photography. Nitric oxide consists of 47 parts of nitrogen gas, and 53 of oxygen gas, by weight; and of equal parts in bulk, without any condensation. The constitution of this gas, and the play of affinities which it exercises in the formation of sulphuric acid, are deeply interesting to the chemical manufacturer.

The *Hyponitrous Acid* (*Salpetrigesäure,* Ger.), like the preceding compound, deserves notice here, on account of the part it plays in the conversion of sulphurous into sulphuric acid, by the agency of nitre. It is formed by mingling four volumes of binoxide of nitrogen with one volume of oxygen; and appears as a dark-orange vapour, which is condensable into a liquid at a temperature of 4° below zero, Fahr. When distilled, this liquid leaves a dark yellow fluid. The pure hyponitrous acid consists of 37·12 nitrogen and 62·88 oxygen; or of two volumes of the first, and three of the second. Water converts it into nitric acid and binoxide of nitrogen; the latter of which escapes with effervescence. This acid oxidises most combustible bodies with peculiar energy; and though its vapour does not operate upon dry sulphurous acid, yet, through the agency of steam, it converts it into sulphuric acid, itself being simultaneously transformed into binoxide of nitrogen; ready to become hyponitrous acid again, and to perform a circulating series of important metamorphoses. See Sulphuric Acid.

NITROGEN, PROTOXIDE OF, or *Nitrous Oxide* (*Protoxide d'azote*, Fr.; *Stickstoffoxydul*, Ger.), NO ($\mathbf{N^2O}$), is a gas which displays remarkable powers on the system when inhaled, causing in many persons unrestrainable feelings of exhilaration, whence it has been called the laughing or intoxicating gas; but the effects often vary. When pure this gas does not seem to be injurious; but the bad effects which sometimes follow its use are most probably due to the use of the gas when not quite pure. It is now used by dentists and surgeons as an anæsthetic.

It was first discovered by Dr. Priestley in 1776, and was afterwards studied by Sir H. Davy, who called it nitrous oxide; it was Davy also who first observed its stimulating effects when taken into the lungs.

It is prepared by heating solid nitrate of ammonia in a flask, provided with a bent tube to carry away the gas; care must be taken in applying the heat, to avoid the tumultuous disengagement of the gas; the nitrate melts and enters into gentle ebullition, and the gas is steadily evolved. If too much heat be applied, the flask becomes filled with white fumes, which have an irritating odour, and the gas which comes over is little else than nitrogen. Protoxide of nitrogen should always be collected over warm water, as cold water dissolves nearly its own volume of this gas. The following equation expresses the decomposition of the nitrate of ammonia:—

$$NH^4NO^6 = 2NO + 4HO \quad (\mathbf{NH^4NO^3 = N^2O + 2H^2O})$$

the only products being water and protoxide of nitrogen. Protoxide of nitrogen, at ordinary temperatures, is a colourless, transparent, and almost inodorous gas, of distinctly sweet taste. Its specific gravity is 1·525; 100 cubic inches weigh 47·29 grains; it is therefore much heavier than atmospheric air. It supports the combustion of a taper or a piece of phosphorus with almost as much energy as pure oxygen; it is easily distinguished, however, from that gas by its solubility in cold water, and by not forming red fumes when mixed with binoxide of nitrogen. It has been liquefied, although with difficulty; it requiring at 45° Fahr. a pressure of fifty atmospheres; the liquid when exposed under the bell-glass of an air-pump is rapidly converted into a snow-like solid.

When mixed with an equal volume of hydrogen, and fired by the electric spark in the eudiometer, it explodes with violence, and liberates its own measure of nitrogen; every two volumes of the gas contain therefore two volumes of nitrogen, and one volume of oxygen condensed into two volumes. By weight it contains 14 parts of nitrogen to 8 of oxygen. See Laughing Gas.

NITRO-GLUCOSE. When we act on finely-powdered cane-sugar with nitrosulphuric acid, a pasty mass is first formed; if this be stirred for a few minutes, lumps separate from the liquid. When these lumps are kneaded in water, until every trace of acidity is removed, they acquire a white and silky lustre; these are the above-named substance.

NITRO-GLYCERINE. A compound produced by the action of strong nitric and sulphuric acid on glycerine at a low temperature. The following modes of preparation are from Watts's 'Dictionary of Chemistry':—

1. A hundred grammes of syrupy glycerine of specific gravity 1·262 are gradually added to 200 c.c. of nitric acid of specific gravity 1·52, immersed in a freezing mixture, the liquid being continually stirred, the temperature allowed to fall to −10° Cent. before each fresh addition, and never to rise above 0°. A homogeneous mixture having been thus obtained, 200 c.c. of strong sulphuric acid are gradually added, the mixture being still kept below 0°. The oily nitro-glycerine (200 grms.) which then floats on the surface is separated by a tap-funnel from the acid liquid (which yields 20 grms. more of nitro-glycerine on being diluted with water), and dissolved in the smallest possible quantity of ether; the solution is repeatedly shaken with water till the water no longer reddens litmus; the ether evaporated, and the remaining nitroglycerine heated over the water-bath until its weight remains constant. The product

amounts to 184 grms. of pure nitro-glycerine. According to Railton, nitro-glycerine is decomposed by evaporation even *in vacuo* over sulphuric acid at ordinary temperatures.

2. Half an ounce of dehydrated glycerine is poured, with constant stirring, into a mixture of 2 ozs. of oil of vitriol and 1 oz. fuming nitric acid of specific gravity 1·52, the temperature of the mixture being kept below 25° Cent. by external cooling with ice; and as soon as oily drops begin to form on the surface, the mixture is poured, with constant stirring into 50 ozs. of cold water. Nitro-glycerine then separates, and may be purified by washing and drying, in small portions, in a vapour-bath.

According to Gladstone, nitro-glycerine exhibits different properties according to the manner in which it is prepared. Ordinary hydrated glycerine, added to a mixture of 3 pts. sulphuric and 1 pt. fuming nitric acid, is converted into a liquid which detonated violently under the hammer; but anhydrous glycerine treated in like manner, yields a non-explosive body which burns without noise. Both kinds of nitro-glycerine when exposed to a mixture of solid carbonic acid and alcohol become gummy, and assume the appearance of fatty acids; and both decompose spontaneously with evolution of red vapours. A sample of nitro-glycerine, which decomposed in this manner on exposure to summer sunshine, yielded crystals of oxalic acid, together with two liquids, the upper of which contained nitric acid, ammonia, oxalic acid, hydrocyanic acid, and other compounds not examined. Mills found that nitro-glycerine kept a fortnight, no longer exploded when struck, but showed no signs of decomposition or chemical alteration.

Nitro-glycerine is well adapted for blasting, its destructive action being estimated at about ten times that of an equal weight of gunpowder. The first attempts to apply it as a mining agent were by A. Nobel, a Swedish engineer, in 1864. Some experiments were first made with gunpowder saturated with nitro-glycerine. This powder burnt much as usual in the open air, but when confined in shells or blast-holes it produced greater destructive effects than ordinary gunpowder. Nitro-glycerine cannot be employed as a blasting agent in the ordinary way, as the application of a flame from a cannon-fuse would not cause it to explode; but when it is introduced in a suitable case into a blast-hole, and a fuse having a small charge of gunpowder attached to its extremity is fixed immediately above it, the concussion produced by the exploding gunpowder effects the explosion of nitro-glycerine. The use of nitro-glycerine is, however, attended with very great danger, on account of its great liability to explode by concussion or by friction during transport. Moreover, it solidifies at a temperature probably as high as 8° C. (56° Fahr.), and the friction of the frozen particles is very apt to give rise to explosion. Nobel has, however, found that the danger of accidental explosion of nitro-glycerine may be obviated by mixing it with wood-spirit, which renders it non-explosive by percussion or by heat. When required for use, it may be recovered by adding water to the mixture, which precipitates the nitro-glycerine. See EXPLOSIVE COMPOUNDS.

NITRO-MURIATIC ACID, or *Aqua regia* (*Acide nitro-muriatique*, Fr.; *Salpetersalzsäure*, *Königswasser*, Ger.), is the compound menstruum invented by the alchemists for dissolving gold. If strong nitric acid, orange-coloured by saturation with nitrous or hyponitric acid, be mixed with the strongest liquid hydrochloric acid, no other effect is produced than might be expected from the action of nitrous acid of the same strength upon an equal quantity of water; nor has the mixed acid so formed any power of acting upon gold or platinum. But if colourless concentrated nitric acid and ordinary hydrochloric acid be mixed together, the mixture immediately becomes yellow, and acquires the power of dissolving these two noble metals. Mr. E. Davy seems first to have obtained a gaseous compound of chlorine and binoxide of nitrogen in 1830, and a combination of these two constituents was distilled from *aqua regia*, and liquefied by M. Baudrimont in 1843. But it was not until M. Gay-Lussac investigated the subject (*Annales de Chimie*, 3me sér. xxiii. 203; or *Chemical Gazette*, 1848, p. 269) that the true nature of the mutual action of nitric and hydrochloric acids was fully explained. When these two acids are mixed in a concentrated state, a reaction soon commences, the liquid becomes red, and effervescence takes place, from the escape of chlorine and a chloro-nitric vapour. On passing this gaseous mixture through a U-tube, the bent part of which is immersed in a freezing mixture of ice and salt, the chloro-nitric compound is condensed as a dark-coloured liquid, and is thus separated from the chlorine which accompanied it.

Chloro-nitric acid, NO^2Cl^2 ($\mathbf{NOCl^2}$), may be represented as a peroxide of nitrogen, in which two equivalents of oxygen are replaced by two equivalents of chlorine. This chloro-nitric acid does not take any part in the dissolving of gold and platinum, which is effected by the chlorine alone. Chloro-nitric acid may also be formed by mixing the two gases, binoxide of nitrogen and chlorine, in equal volumes, which assume a brilliant orange colour, and suffer a condensation of exactly one-third of their original volume. Another compound of chlorine and binoxide of nitrogen always appears simultaneously with this in variable proportions. Its composition is NO^2Cl ($\mathbf{NOCl}$), and may be represented as nitrous acid, NO^3, in which one atom of oxygen has been replaced by its equivalent of chlorine. It is a vaporous liquid, possessing similar properties to the other, but having a much greater vapour-density.

The theoretical vapour-density of the chloro-nitric acid is 1·74, and that of the chloro-nitrous acid 2·259.

The vapours of both these compounds are decomposed, when conducted into water, into hydrochloric acid and hyponitric acid or nitrous acid. They are also decomposed by mercury; the chlorine combining with the metal, leaving pure binoxide of nitrogen.

Various proportions of nitric and hydrochloric acids are used in making *aqua regia;* sometimes two or three parts, and sometimes six parts of hydrochloric acid to one part of nitric acid; and occasionally chloride of ammonium, instead of hydrochloric acid, is added to nitric acid for particular purposes, as for making a solution of tin for the dyers. An *aqua regia* may also be prepared by dissolving nitre in hydrochloric acid.

NITROUS ACID (NO^3 [$\mathbf{N^2O^3}$]; equivalent, 38), is obtained by mixing four measures of binoxide of nitrogen with one measure of oxygen; they unite and form an orange-red vapour, which, when exposed to a temperature of 0° Fahr., condenses to a thin mobile green liquid. It is decomposed by water, and is converted into nitric acid and binoxide of nitrogen.

$$3NO^3 + HO = HNO^6 + 2NO^2 \quad (\mathbf{3N^2O^3 + H^2O = 2HNO^3 + 2N^2O^2}).$$

On this account it cannot be made to unite directly with metallic oxides; the salts of this acid are therefore obtained by an indirect process. Nitrate of potash, when exposed to a high temperature, is decomposed, losing oxygen and becoming nitrate of potash; some caustic potash is also formed at the same time. To obtain it pure, this is dissolved in water, and while boiling we had nitrate of silver, when we obtain first of all a dark precipitate of oxide of silver, caused by the caustic potash; which is separated by a filter, and on cooling the liquid the nitrate of silver crystallises in white needles, which may be purified by recrystallisation. From this salt the pure nitrites may be obtained; for instance, by adding to a solution of nitrite of silver chloride of potassium we obtain the potash salt.

Hyponitric Acid (NO^4 [$\mathbf{N^2O^4}$]; equivalent, 46), is best procured by distilling, in a coated glass retort, perfectly dry nitrate of lead. Hyponitric acid and oxygen pass over into a receiver, surrounded with a freezing mixture; the former condenses into a liquid, while the oxygen passes off by the safety tube, and only oxide of lead remains in the retort. This hyponitric acid or *peroxide of nitrogen* is a liquid, colourless at −4° Fahr., but is at higher temperatures yellow and orange. It boils at 82° Fahr., gives off a dark red vapour, which becomes almost black when further heated. A beautiful lead-salt of this acid has been discovered by M. Péligot. It is formed by digesting a dilute solution of nitrate of lead with finely-divided metallic lead at a temperature between 150° and 170° Fahr. See Watts's 'Dictionary of Chemistry.'

NOBLE METALS. This was a division formerly adopted: it included those metals which can be separated from oxygen by heat alone; these are mercury, silver, gold, platinum, palladium, rhodium, iridium, and osmium.

NOILS is the term used in the worsted trade for the short wool taken from the long staple by the process of combing, and is used to give apparent solidity or thickness in the handling of cloth.

NON-INFLAMMABLE FABRICS. See MUSLIN, *non-inflammable.*

NOPAL is the Mexican name of the plant *Cactus opuntia*, upon which the cochineal insect breeds.

NORDHAUSEN ACID. Brown fuming sulphuric acid, used as a solvent of indigo. See SULPHURIC ACID.

NORIUM. The name of a metal which was thought to be always associated with zirconium. It is, however, doubtful if it has any existence.

NOTATION. In 1815, Berzelius, the chemist, proposed a system of notation in which the use of initial letters was adopted to signify the elementary bodies. This idea has been continued and improved upon by modern chemists. The modern system of notation endeavours to express by initial letters, figures, and a few simple signs, not merely the elements, but their combinations. The modern system of notation will be best studied in Watts's 'Dictionary of Chemistry.' See FORMULÆ, CHEMICAL.

NOYAU. A liquor flavoured with the kernels of peach-stones. An inferior kind is flavoured with the essential oil of bitter almonds.

NUGGET, or *Pepita*. A lump of gold as found in nature. Usually those masses are found in hollow spaces, beneath the deposits which have been made by ancient torrents. They are, of course, always derived from the quartz-lode in which the gold has been originally deposited. These lodes have been worn down by the long-continued action of water, and by the same agent the more friable quartz has been removed, the gold being left eventually nearly pure. See GOLD.

The following are the weights of a few of the largest nuggets which have been found:—

	lbs.	oz.
'Welcome Nugget,' Ballarat, Victoria	168	3
A mass found in the Ural Mountains	79	0
The Dascombe nugget, found at Bendigo	27	8
Another from the same locality	28	0
Ditto Ditto	45	0
From Forest Creek, Mount Alexander, Victoria	27	6

NUT-GALLS. See GALL-NUTS.

NUT-OIL. An oil professedly obtained from walnuts, which is thought to be superior to the best linseed-oil for delicate pigments; when deprived of its mucilage it is pale, transparent, and limpid. See OILS.

NUTMEG (*Muscade*, Fr.; *Muskatennuss*, Ger.) is the fruit of the *Myristica moschata*, of Thunberg, *M. officinalis* of Linnæus, a very beautiful tree of the family of the *Laurineæ* of Jussieu.

The nutmeg grows in the Molucca Islands; it is cultivated in Java, Singapore, Sumatra, and many islands of the Indian Ocean, and also in some parts of the West Indies. The Dutch, it is said, endeavoured to confine the growth of the nutmeg to three of the Banda Isles; but their attempts were frustrated by a pigeon, called the nutmeg-bird, which, extracting the nutmeg from its pulpy pericarp, digests the mace, but voids the nutmeg in its shell, which, falling in a suitable situation, readily germinates. Young plants thus obtained are used for transplanting into nutmeg-parks. In the Banda Isles there are three harvests annually; the ripe fruit is gathered by means of a barb attached to a long stick, the mace separated from the nut, and both separately cured.

Mace is prepared for the market by drying it for some days in the sun: some flatten it by the hands in single layers; others cut off the heels, and dry the mace in double blades.

Nutmegs require more care in curing, on account of their liability to the effects of an insect (the nutmeg-insect). They are well and carefully dried in their shells by being placed on hurdles, or gratings, and smoke-dried for about two months by a slow wood fire, at a heat not exceeding 140° Fahr.

Dr. Pereira informs us that, 'In the London market, the following are the sorts of round nutmegs distinguished by the dealers:—

'1. *Penang nutmegs.*—These are unlimed or brown nntmegs. They are sometimes limed here for exportation, as on the Continent the limed sort is preferred. According to Newbold the average amount annually raised at Penang is 400 piculs (of 133½ lbs. each).

'2. *Dutch*, or *Batavian nutmegs.*—These are limed nutmegs. In London they scarcely fetch so high a price as the Penang sort.

'3. *Singapore nutmegs.*—These are a rougher, unlimed, narrow sort, of somewhat less value than the Dutch kind. According to Mr. Oxley, 4,085,361 nutmegs were produced in Singapore in 1848, or about 252 piculs (of 133½ lbs. each), but the greater number of trees had not come into full bearing; and it was estimated that the amount would in 1849 be 500 piculs.'

The *long* or *wild-nutmeg* is also met with in commerce.

Mace of two kinds is found in the market—the *true* and *false*.

Of the true maces there are the following varieties:—

1. *Penang mace.*—This fetches the highest price. It is flaky and spread. The annual quantity produced in Penang is about 130 piculs (of 133½ lbs. each).

2. The *Dutch* or *Batavian mace* is a fleshy sort; it is not considered equal to the Penang mace, and rarely fetches so high a price.

3. The *Singapore mace* is regarded as very inferior to the other sorts. It is, however, often of fine flavour and good colour, and, when selected, is sold with the better sorts.

The *wild* or *false* mace is devoid of aromatic flavour.

The uses of nutmegs and mace in dietetics are well known. An essential oil of nutmegs (*Oleum myristicæ*) is obtained by submitting water and nutmegs to distillation. By distillation they yield from 9 to 10 lbs. of essential oil for every cwt.

This volatile oil is largely imported into this country, and is used for scenting soap, and in perfumery.

NUTMEG, BUTTER OF. See OILS.

NUTRITION, or that process by which a living being is nourished and its growth maintained, has so important a bearing upon the practical question of health, that a brief exposition of the subject, especially with reference to the food of man, may fairly find a place in this work.

Every living animal organism needs a constant supply of matter from without, partly to furnish materials for those chemical changes by which the forces of the organism are developed, and partly to compensate for the wear and tear which the structure suffers in the performance of its various functions. The quantity of matter thus required in the shape of food varies in different organisms, and in the same organism under different conditions; indeed, the more work an animal performs the greater its waste, and consequently the greater the amount of food which it requires. It has been calculated that a full-grown man of average weight, in ordinary activity, loses daily about 4,600 grains of carbon and about 300 grains of nitrogen. It is clear that if the body is to remain in equilibrium, neither losing nor gaining in weight, these quantities of carbon and nitrogen must be supplied from without, and presented in a form available for nutrition.

All kinds of food have been divided into two groups: those containing nitrogen, and those destitute of this element. To the *nitrogenous* group belong all proteinaceous compounds, consisting mainly of carbon, hydrogen, oxygen, and nitrogen, with more or less sulphur and phosphorus. This group includes *albumen*, or white-of-egg; *syntonin*, which forms the chief constituent of muscular tissue or lean meat; *fibrin*, one of the derivatives of blood; *casein*, obtained from cheese; *gluten*, from flour; and *legumin*, from peas and beans. To the *non-nitrogenous* group belong all amylaceous compounds, such as starches, sugars, and gums: these contain only carbon, hydrogen, and oxygen; and, as the hydrogen and oxygen exist in exactly the proper proportion to form water, they may be appropriately called *carbo-hydrates*, consisting as they do of carbon and the elements of water. The non-nitrogenous food-stuffs also include all animal and vegetable fats and oils; these consist, likewise, of carbon, hydrogen, and oxygen, but the hydrogen is in excess of that necessary to form water with the oxygen. Liebig termed the nitrogenous foods *elements of nutrition* or *flesh-formers*, since he believed that they only were capable of conversion into blood, and therefore of building up the body; whilst he characterised the non-nitrogenous principles as *elements of respiration* or *heat-givers*, since he maintained that they served merely to sustain the temperature of the body by the slow combustion of their carbon and hydrogen by means of the atmospheric oxygen taken into the system through the lungs. It is now known, however, that this sharp limitation of functions to each class of foods is not strictly correct. It is true that nitrogenous compounds are absolutely necessary to replace the nitrogen which is carried out of the system in the shape of urea; yet they may also contribute to the production of heat by oxidation of part of their carbon and hydrogen. But although proteinaceous compounds are thus absolutely necessary to the support of life, and may even be used alone, there are strong physiological and economical reasons in favour of their due admixture with the non-nitrogenous kinds of food. It should not be forgotten that it is necessary to introduce into the diet certain mineral substances, such as common salt and the various saline matters present in most animal and vegetable substances. In such a typical food as milk we find the proteinaceous, saccharine, oleaginous, and mineral matters so nicely balanced, that all the nutritive functions in infancy are well sustained by this single article of diet. Bread and meat may also be cited as a representative mixed diet; the gluten of the bread and the lean of the meat representing the nitrogenous principles, and the starch of the bread and the fat of the meat being non-nitrogenous, whilst mineral matters are found in both. The amount of carbon and nitrogen which was previously stated to be daily excreted by a man of ordinary activity may be replaced by a diet made up of about 2 lbs. of bread and ¾ lb. of meat per day.

For further information on this subject, see Watts's 'Dictionary of Chemistry.'

The following remarks on the law regulating the balance of the food are retained from the longer article by the late Robert Dundas Thomson which appeared in the last edition, since they place the question in a very clear light.

During the present century a large amount of experiment has clearly demonstrated that animals cannot subsist on starch, sugar, or other foods destitute of nitrogen; and therefore, the inference was fairly deduced that the animal system possessed no power of assimilating nitrogen from the air (*Magendie*). Further consideration led to the conclusion that milk constitutes the type of what nutriment should be, since it is supplied for animal support by nature at the earliest period of human existence

(*Prout*), and contains nitrogenous matter, oil, and sugar. Afterwards, experiments were made to determine the amount of nitrogen in food, and the relative value of nutriment was tabularly stated, in dependence on the ratio of nitrogen present in each species (*Boussingault, Ann. de Chim.* lxiii. 225, 1836), a method which has been superseded. It was subsequently inferred that nitrogenous matter supplied the waste of the muscular tissue, while the non-nitrogenous constituents of the food served for respiratory purposes, or the production of animal heat by obviating the too rapid transformation of the muscular elements of the body (*Liebig, Organische Chemie*, 1842). This was the true key to the solution of the problem as to the function of the nitrogenous and non-nitrogenous food, and it laid open a wide field for enquiry in reference to the applications of rational systems of dieting to the animal system. For example, it was found in a series of experiments conducted for the British Government in 1845, that in a stall-fed cow in one day, taken from an average of several months, the amount of food conveyed into the circulation of the blood of the animal, was 14·56 lbs. weight; and when the nature of this mass of nutriment was subjected to chemical inquiry, it appeared that 1·56 lb. consisted of nitrogenous matter, and 13 lbs. of non-nitrogenous food. When the relation between these two quantities is calculated, it results that the nitrogenous is to the non-nitrogenous food as 1 to 8·33, in the case of an animal at rest. This observation led to researches into the relative constitution of food as employed by different nations; and the deduction was made, that it is a law of nature that animals under the different conditions of rest and exertion, require food in which the relation of the nutrient or nitrogenous food is different in reference to the non-nitrogenous or heat-producing (calorifiant) constituent:—that the animal system may be viewed, as in an analogous condition to a field, from which different crops extract different amounts of matter, which must be ascertained by experiment;—an animal at rest consuming more calorifiant food, in relation to the nutritive constituents, than an animal in full exercise. From the analyses then instituted the following table was constructed:—

Approximate relation of nutritive or nitrogenous to calorifiant matter.

		Relation of Nutritive to Calorifiant Matter.
Milk food for a growing animal		1 to 2
Beans		1 „ 2½
Peas Linseed		1 „ 3
Scottish oatmeal		1 „ 5
Wheat flour Semolina Indian corn Barley	Food for an animal at rest	1 „ 7 to 1 „ 8
Potatoes		1 „ 9
East Indian rice		1 „ 10
Dry Swedish turnips		1 „ 11
Arrowroot Tapioca Sago		1 „ 26
Starch		1 „ 40

These proportions will consequently vary considerably according to the richness of the grain or crop, and hence similar tables which have been subsequently published by others will be found to differ in some of the details from the preceding data; but the facts now stated—given as approximate—are probably as good averages as could be selected.—R. D. Thomson, 'Medico-Chirurgical Trans.,' xxix., and 'Experim. Researches on the Food of Animals,' 1846, p. 162.

The Table on the following page is an illustration of the law of the equilibrium of the food.

The table is read thus:—an English soldier consumes weekly 11,703 grammes (a gramme equal to 15·44 grains) of food. In this food 1,119 grammes are nitrogenous or flesh-forming matter; 3,937 non-nitrogenous or heat-producing material; 152 mineral substance; the organic matter containing 2,219 grammes carbon. The relation of the nitrogenous to the non-nitrogenous matter is as 1 to 3·50. From this table the results have been deduced that soldiers and sailors consuming 35 ounces of nitrogenous or flesh-forming food weekly, and 70 to 74 ounces of carbon, the proportion of the carbon in the flesh-forming, to that in the respiratory or heat-forming food, is as one to three. Older persons require only 25 to 30 flesh-forming matter weekly, and from 72 to 78 respiratory food; the relation of the carbon in these is as 1 to 5. Boys of from ten

	Weekly consumption	Nitrogenous matter	Non-nitrogenous matter	Mineral constituents	Carbon	Relation of nitrogenous to non-nitrogenous matter
DIETARIES OF SOLDIERS AND SAILORS	grms.	grms.	grms.	grms.	grms.	As 1 to
English soldier	11703	1119	3937	152	2219	3·50
„ „ in India . . .	9080	1057	3195	74	2053	3·02
„ sailor (fresh meat) . .	9350	1078	3185	98	2184	2·95
„ „ (salt meat) . .	8978	1274	4092	187	2706	3·69
Dutch soldier, in war . . .	6130	1090	3160	57	2293	2·90
„ „ in peace . . .	11857	759	3306	128	2191	4·35
French soldier.	10742	1029	3955	143	2639	3·84
Bavarian soldier	7492	652	3161	103	1933	4·85
Hessian soldier	13096	712	4210	...	2384	5·91
DIETARIES OF CHILDREN						
Christ's Hospital, Hertford . .	6687	531	1897	76	1213	3·57
„ London . .	7488	534	2378	88	1453	4·45
Chelsea Hospital boys' school . .	7585	401	2888	183	1785	7·20
Greenwich Hospital „ . .	7151	570	2685	81	1637	4·71
DIETARIES OF AGED PERSONS						
Greenwich pensioners . . .	8328	757	3784	109	2242	4·87
Chelsea „ . . .	10278	905	3487	144	2416	3·85
Gillespie's Hospital, Edinburgh .	4829	651	2858	73	2210	4·39
Trinity Hospital „ .	5944	608	3014	104	1774	4·95
DIETARIES OF AGED POOR						
1st class	...	626	2743	101	1681	4·38
2nd „	...	463	2773	89	1582	5·99
3rd „	...	488	3092	121	1716	6·33
4th „	...	595	3617	123	2101	6·08
5th „	...	479	2988	111	1694	6·24
6th „	...	454	2725	88	1535	6·00
Mean of all English counties . .	...	681	3065	...	1796	4·50
St. Cuthbert's, Edinburgh . .	5418	458	2766	102	1454	6·04
City poorhouse „ . .	3312	412	1547	54	975	3·75
DIETARIES OF ENGLISH PRISONS						
2nd class, above 7 not above 21 days .	6393	472	3463	107	1834	7·34
3rd „ 21 „ 6 weeks' hard labour	9144	565	3827	125	2091	6·77
4th, 7th, 8th classes, above 6 weeks' not above 4 months' hard labour .	8405	649	3900	156	2162	6·00
5th class, above 4 months' hard labour	10092	628	4042	131	2270	6·43
ARCTIC AND OTHER DIETARIES						
Esquimaux	...	7740	39628	...	34830	5·12
Yacut	...	3093	19814	...	29907	6·46
Boschesmen	...	1777	11393	...	17182	6·41
Hottentots	...	1323	12394	...	18699	9·36
Farm labourers, Gloucestershire .	5065	825	3299	34	2323	3·97

to twelve years of age require 17 ounces of flesh-forming matter, the relation of the carbon in the flesh-forming to the heat-producing aliment being as 1 to 5½. In workhouses and jails, less heat-producing matter is consumed, in consequence of the shelter and heat supplied artificially to the inmates. In prisons, where hard labour is in force, the consumption of flesh-forming or nitrogenous nutriment increases. It has been estimated that in a man weighing 140 lbs., the weight of the flesh-forming matter of the blood is 4 lbs., that of the muscular tissue 27½lbs., and in the bones 5lbs., making a total of 36½ lbs.; and that in the course of 18 weeks these 36½ lbs. are introduced into the system. (Playfair, 'New Edin. Phil. Journal,' 1854, 56,262).

NUX VOMICA; *Strychnos nux vomica*, Linn. The seeds of a tree growing in

Coromandel and other parts of India and Ceylon. From these strychnine is obtained. See Strychnine.

Nux vomica bark was at one time confounded with Angustura or Cusparia bark, and serious consequences might have ensued but that the error was discovered in time. It is now rarely seen.

O

OAK. (*Chêne*, Fr.; *Eich*, Ger.) This well-known European tree is so familiar that it scarcely requires any description. The varieties generally known in England are the following:—*Quercus pedunculata*, Common Oak, which is a native of Britain, and is largely employed in building ships. *Quercus ilex*, Evergreen Oak: this tree is not a native, but has been cultivated in Britain from the most remote period. *Quercus cerris*, Turkey Oak: introduced into this country more than a century since. *Quercus coccinea*, Scarlet Oak: the leaves changing with the first frosts to a brilliant scarlet. *Quercus sessiliflora*, Common short-stalked Oak: this is said to excel for building purposes any other oak.

Oak, Bog. Oak trees which have been buried for a long period in peat bogs, become intensely black; and this 'bog oak' is employed in the manufacture of furniture and articles of ornament.

OAK-BARK. The oak tree is generally barked from the beginning of May to the middle of July. The barkers make a longitudinal incision with a mallet furnished with a sharp edge, and a peculiar incision by means of a barking-bill. The bark is then removed by peeling-irons, the separation being promoted, when necessary, by beating the bark. It is collected and stacked in pieces about 2 feet long. Oak-bark contains, according to Braconnot, tannic acid, tannates of the earths, gallic acid, pectin, and lignin. Davy, in his 'Agricultural Chemistry,' gave the following as the relative quantities of tannin contained in oak-bark:—

480 lbs. of entire bark of a middle-sized oak cut in spring	29 lbs.
„ coppice oak	32 „
„ oaks cut in autumn	21 „
White interior cortical layers	72 „

See Leather; Tan; Tanning.

OAK, DYER'S. See Gall-Nuts.

OAK-GALLS. See Gall-Nuts.

OAST. *Hop Oast.* A kiln for drying hops, heated by a stove with flues.

OATS. (*Avoine*, Fr.; *Hafer*, Ger.) The oat is extensively cultivated in these islands, especially in Scotland. In fact, Scotland is the country admittedly the best fitted for the growth of oats. The estimated number of acres of cultivated land in Scotland is 2,400,000; of which 220,000 are under wheat, 280,000 under barley, and 1,270,000 under oats.

Oats returned as sold in various Market Towns in England and Wales.

	1865	1866	1867	1868	1869	1870	1871	1872
	qrs.	qrs.	qrs.	qrs.	qrs.	qrs.	qrs.	qrs.
January	34,216	32,801	29,956	33,726	24,102	19,198	21,524	19,354
February	36,896	42,600	31,612	56,789	23,012	20,952	28,045	23,586
March	33,607	39,574	35,939	37,381	15,946	24,606	28,299	28,203
April	23,423	17,034	17,841	18,856	11,899	21,852	21,694	18,489
May	16,739	9,911	14,519	17,768	10,517	12,519	7,928	10,447
June	8,833	9,301	9,670	6,500	5,838	11,973	5,556	9,282
July	9,586	4,779	6,444	4,672	4,754	8,503	5,017	5,442
August	8,020	5,706	7,042	7,544	6,060	8,932	4,761	4,156
September	26,029	12,417	16,027	14,564	11,992	16,087	12,558	9,757
October	24,227	21,634	35,528	15,355	19,449	18,664	15,103	16,985
November	19,092	22,520	40,460	15,755	13,415	17,230	18,677	21,499
December	36,656	36,445	39,738	20,957	14,723	25,575	27,955	22,170
Total	217,315	254,722	284,776	249,867	161,707	206,091	197,122	184,375

These returns of the sale of oats were obtained from 290 towns previous to Jan. 1, 1865, and from 150 towns since. They represent, therefore, but very imperfectly the quantity of oats produced in these Islands. Our agricultural statistics are, unfortunately, in a very unsatisfactory state.

OBSIDIAN. A glassy mineral; so called, it is stated, from *Obsidius*, a Roman, who brought it from Africa. It is a true volcanic glass, and occurs in streams, or in detached masses near many volcanic mountains. It was largely employed by the ancient Mexicans as a material for knives and other cutting-instruments.

OCCLUSION. A term applied by the late Professor Graham to the absorption of gases by metals, and the shutting up of the same. Hydrogen in the nascent state is absorbed in large quantities by palladium, and to some extent by other metals. This gas is held by the metal until exposed to heat or other conditions, by which it is liberated. *Occlude* is an old word in our language signifying *to shut up*. See Latham's 'Dictionary of the English Language.'

OCHRE. (*Ocre*, Fr.; *Ocker*, Ger.) Ochre is, truly, a peroxide of iron and water; but a native earthy mixture of silica and alumina, with oxide of iron in various proportions, and sometimes calcareous matter and magnesia, is usually regarded as ochre. The term is applied, indeed, without any great degree of exactness, to any combinations of the earths with iron, which can be employed for pigments and the like. According as the colour varies, we have *yellow*, *brown*, and *red* ochres.

In Cornwall considerable quantities of ochres are obtained by carefully washing the ferruginous mud, which is separated from poor tin and copper ores after they have been submitted to the action of the stamps and the ordinary processes of washing and roasting.

The iron paints formerly prepared by Mr. Wolston of Brixham must be regarded as ochres. They are found in connection with iron lodes which exist in the rocks around the coast. These paints have been employed for several years in the Royal Naval Arsenals and other government establishments. The wood and iron huts of our camps have been painted with them. They have also been employed for coating the boilers of steam-engines.

A large supply of ochre is obtained from the island of Anglesea, but the ochres of Anglesea are not natural; they are artificial productions, formed in the lakes, into which scrap-iron is thrown to precipitate the copper contained in the water, and forms very large accumulations of the oxide of iron, which is sold as ochre. There is now a large demand for these iron-ochres, as they are extensively employed for the purification of gas.

In the more recent formations ochre occurs in beds some feet thick, which lie generally above the Oolite, are covered by sandstone and quartzose sands, more or less ferruginous, and are accompanied by grey plastic clays, of a yellowish or reddish colour. The ochry earths are prepared by grinding and washing; in some cases they are also exposed to the action of the fire, to increase the oxidation of the iron, and deepen the colour.

The following is a section of the ochre-pits at Shotover Hill, near Oxford, where the Oxford ochre is obtained:—

Beds of highly ferruginous grit, forming the summit of the hill	6 feet.
Grey sand	3 „
Ferruginous concretions	1 „
Yellow sand	6 „
Cream-coloured loam	4 „
Ochre	6 inches.

Beneath this there is a second bed of ochre, separated by a thin bed of clay.

Reddle, employed for marking sheep in Devonshire, and a variety found near Rotterdam (which is much used for grinding spectacle-glasses at Sheffield), may be said to belong to this class. See OXIDES OF IRON, *for polishing*.

Bole, *Armenian Bole*, or *Lemnian Earth*, may be ranked with the ochres. See BOLE, and TIERRA DI SENNA.

The *Ochre of Bitry* and *Italian Rouge* are ochres which are found principally near Vierzon and St. Amand (Nièvre). The ochres from Holland are also much esteemed.

It will thus be apparent that ochre occurs in all formations, from the earliest known rocks—where it is probably due to the decomposition of the sulphides of iron—up to the alluvial deposits of yesterday; in many of which ochreous formations may be watched in the progress.

Ochre in mineralogy is a term applied to many products of decomposition, as, *cobalt-ochre*, *bismuth-ochre*, *chrome-ochre*, *antimony-ochre*, &c.

OCUBA WAX. A vegetable wax, collected on the shores of the Amazon from the fruit of the *Myristica Ocuba*. This wax is easily bleached; and in Brazil it is used extensively for candles.

ODOMETER. An instrument which can be attached to the wheel of a carriage, which, moving regularly with the wheel, indicates the distance passed over in any journey.

ODONTOGRAPH. An instrument, invented by Professor Willis, to enable the millwright to draw and design, with great uniformity and precision, the teeth of wheels.

ŒNANTHIC ETHER is used for flavouring wines. Lichtenberger of Bavaria exhibited it so largely in 1862 that Dr. Hofman remarks: 'To judge from the quantities exhibited, this article would seem to be manufactured in a systematic manner, and upon a very large scale. The substance is a solid, and, according to all appearance, a pure definite compound, the chemical investigation of which would present considerable interest.'

OIL-CAKE, or **OIL-SEED CAKE.** After the expression of the oil, especially from linseed, the mass remaining is so called. It is much used for feeding cattle. Our *Importations* of oil-seed cake have been as follow:—

	Tons		Tons
1867 . . .	121,838	1870 . . .	158,453
1868 . . .	162,339	1871 . . .	162,804
1869 . . .	159,295	1872 . . .	134,300

OIL OF VITRIOL is the old name of concentrated Sulphuric Acid.

OILS (*Huiles*, Fr.; *Oele*, Ger.) form a class of valuable and interesting substances, and are divided into two great classes, viz. fixed or fatty oils, and volatile or essential oils. The members of one class differ greatly, in nearly every respect, from those of the other class. The former are usually bland and mild to the taste; the latter hot and pungent. The term *distilled*, applied especially to the last class, is not quite correct, since some of them are obtained by expression, as the whole of the first class may be, and commonly are. All the known fatty substances found in organic bodies, without reference to their vegetable or animal origin, are, according to their consistence, arranged under the chemical heads of oils, butters, and tallows. They all possess the same ultimate constituents—carbon, hydrogen, and generally oxygen, and some few of the essential oils, sulphur also; but, as a class, they are noted for containing a large proportion of carbon, which renders them valuable as food, and as sources of light.

Oils have been known and used from the remotest ages. The olive-tree is frequently mentioned by Moses; and it appears to have been introduced into Europe at an early period, probably by the Greeks.

Mineral and coal oils are noticed under the respective heads of Naphtha; Petroleum; Shale, and Mineral Oils, &c.

For the present we shall only take notice of the fixed or fatty oils. These are widely distributed through the organs of vegetable and animal nature. They are found in the seeds of many plants, associated with mucilage, especially in those of the dicotyledonous class, occasionally in the fleshy pulp surrounding some seeds, as the olive; also in the kernels of many fruits, as of the nut and almond tree; and, finally, in the roots, barks, and other parts of plants. In animal bodies, the oily matter occurs enclosed in thin membranous cells, between the skin and the flesh, between the muscular fibres, between the abdominal cavity in the omentum, upon the intestines, and round the kidneys, and in a bony receptacle of the skull of the spermaceti whale; sometimes in special organs, as, of the beaver in the gall-bladder, or mixed in a liquid state with other animal matters, as in the milk.

Braconnot, but particularly Raspail, has shown that animal fats consist of small microscopic, partly polygonal, and partly reniform particles, associated by means of their containing sacs. These may be separated from each other by tearing the recent fat asunder, rinsing it with water, and passing it through a sieve. The membranes being thus retained, the granular particles are observed to float in the water, and afterwards to separate, like the globules of starch, in a white, pulverulent, semi-crystalline form. The particles consist of a strong membranous skin, enclosing *stearine* and *elaine*, or solid and liquid fat, which may be extracted by trituration and pressure. These are lighter than water, but sink readily in spirit of wine. When boiled in strong alcohol, the oily principle dissolves, but the fatty membrane remains. These granules have different sizes and shapes in different animals: in the calf, the ox, the sheep, they are polygonal, and from $\frac{1}{70}$th to $\frac{1}{450}$th of an inch in diameter; in the hog they are kidney-shaped, and from $\frac{1}{70}$th to $\frac{1}{140}$th of an inch; in man they are polygonal, and from $\frac{1}{70}$th to $\frac{1}{900}$th of an inch; in insects they are usually spherical, and not more than $\frac{1}{600}$th of an inch.

The fat oils are contained in that part of the seed which gives birth to the cotyledons; they are not found in the plumula and radicle. Of all the families of plants the *Cruciferæ* are the richest in oleiferous seeds; and next to these are the *Drupaceæ*, *Amentaceæ*, and *Solaneæ*. The seeds of the *Gramineæ* and *Leguminosæ* contain rarely more than a trace of fat oil. One root alone, that of the *Cyperus* *esculenta*, contains a fat oil. The quantity of oil furnished by seeds varies not only with the species, but, in the same seed, with culture and climate. Nuts contain about half their weight of oil; the seeds of the *Brassica oleracea* and *B. campestris*, one-third; the variety called colza in France, two-fifths; hemp-seed, one-fourth; and linseed from one-fourth to one-fifth. Unverdorben states that a last, of 10 quarters, of linseed, yields 40 ahms = 120 gallons English, of oil; which is about 1 cwt. of oil per quarter.

The fat oils, when first expressed without much heat, taste merely unctuous on the tongue, and exhale the odour of their respective plants. They appear quite neutral by litmus-paper. Their fluidity is very various, some being solid at ordinary temperatures, and others remaining fluid at the freezing-point of water. Linseed-oil, indeed, does not congeal till cooled from 4° to 18° below 0° Fahr. The same kind of seed usually affords oils of different degrees of fusibility; so that in the progress of refrigeration one portion concretes before another. Chevreul considered all the oils to be composed of two, and sometimes three, different species, viz. *stearine*, *margarine*, and *oleine*; the consistence of the oil or fat varying as either of these predominates. These bodies are all compounds of *glycerine*, with a fatty acid. At all ordinary temperatures oleine is liquid; margarine is solid, and melts at 116° Fahr.; stearine is still more solid, and melts at about 130° Fahr. The two latter may be prepared from pure mutton fat, by melting it in a glass flask, and then shaking it with several times its weight of ether; when allowed to cool, the stearine crystallises out, leaving the margarine and oleine in solution. The soft mass of stearine may be strongly pressed in a cloth, and further purified by re-crystallisation from ether. It forms a white friable mass, insoluble in water, and nearly so in cold alcohol; but boiling spirit takes up a small quantity. It is freely soluble in boiling ether; but, as it cools, nearly all crystallises out.

Margarine may be prepared from the ethereal mother-liquor, from which the stearine has separated, by evaporating it to dryness; the soft mixture of margarine and oleine is then pressed between folds of blotting-paper; the residue again dissolved in ether, from which the margarine may now be obtained tolerably pure. It very much resembles stearine, but, as above mentioned, has a lower melting-point.

It is rather doubtful if oleine has ever been prepared in a perfectly pure state, the separation of the last particles of margarine being very difficult. It may be obtained by subjecting olive-oil to a freezing mixture, when the margarine will nearly all separate, and the supernatant fluid oil may be taken as oleine.

Oleine may also be procured by digesting the oils with a quantity of caustic soda, equal to one half of what is requisite to saponify the whole; the stearine and margarine are first transformed into soap, then a portion of the oleine undergoes the same change, but a great part of it remains in a nearly pure state. This process succeeds only with recently-expressed or very fresh oils.

The fat oils are completely insoluble in water. When agitated with it, the mixture becomes turbid, but if it be allowed to settle the oil collects by itself upon the surface. This method of washing is often employed to purify oils. Oils are little soluble in alcohol, except at high temperatures. Castor oil is the only one which dissolves in cold alcohol. Ether, however, is an excellent solvent of oils, and is therefore employed to extract them from other bodies in analysis; after which it is withdrawn by distillation.

Fat oils may be exposed to a high temperature without undergoing much alteration; but when they are raised to nearly their boiling-point, they begin to be decomposed. The vapours that then rise are not the oil itself, but certain products generated in it by heat. These changes begin somewhere under 600° of Fahr., and require for their continuance temperatures always increasing.

If, instead of raising the heat generally, we submit the fats or oils directly to a red heat, as by passing them through a red-hot tube, they are decomposed completely, and are almost entirely transformed into gaseous carburetted hydrogens, the mixture of which serves for illuminating purposes, and yields a far better light than ordinary coal-gas. In places where the seed and fish oils can be procured at a low price, these substances might be employed with great advantage for this purpose.

Action of Alkalis on the Oils.—When the fat or oils are boiled with potash or soda, they are decomposed into glycerine and the fatty acids, with assimilation of water by both the glycerine and the fatty acids. Thus oleine yields glycerine and oleic acid; margarine, glycerine and margaric acid; and stearine, glycerine and stearic acid. The glycerine dissolves in the water and the fatty acids unite with the alkalis, forming soaps (see SOAPS). The action of ammonia on the oils is much less energetic; it, however, readily mixes with them, forming a milky emulsion, called volatile liniment, used as a rubefacient in medicine. Upon mixing water with this, or by neutralising the ammonia by an acid, or even by mere exposure to the air, the ammonia is removed, and the oil again collects. By the prolonged action of ammonia, however, on the oils, true ammoniacal soaps are formed, and at the same time a peculiar body is formed, called by its discoverer (Boullay) *margaramid.*

It is obtained by boiling the ammoniacal soap with water, when the margaramid swims on the top, and when allowed to cool solidifies. It is purified by solution in boiling alcohol, which deposits it again on cooling in the crystalline state. It is a white, perfectly neutral solid, unalterable in the air, insoluble in water, very soluble in alcohol and ether, especially by the aid of heat. It fuses at about 140° Fahr., and burns with a smoky flame. It is decomposed when boiled with potash or soda, forming true soaps, with the liberation of ammonia, and also by acids of a certain degree of concentration.

The alkaline earths and some metallic oxides unite with the fatty acids, forming insoluble soaps, which in the case of lead is called a plaister.

After glycerine and the fatty acids have once been separated, they do not readily again unite; but Berthelot has succeeded in effecting this, by enclosing them for a considerable time in a sealed tube, and subjecting them to a more or less elevated temperature, when the true oils are again produced.

Action of Acids upon the Oils.—Sulphuric acid (concentrated), when added to the oils, unites with them energetically; the mixture becomes heated, and, unless cooled, chars with the liberation of sulphurous acid. When the mixture is cooled the fats and oils undergo a similar change to that which the alkalis effect. There is formed some sulpho-glyceric acid, as well as combinations of margaric and oleic acids with sulphuric acid; these latter are again decomposed when mixed with water, liberating the fatty acids.

Nitric Acid (concentrated) attacks the fatty bodies very rapidly, sometimes causing ignition. Dilute nitric acid acts less powerfully, forming the same compounds which we obtain by acting on the several constituents of the oils separately.

Hyponitric acid, or *nitrous acid,* converts the oleine of the non-drying oils into a solid fat, *elaidine.*

Chlorine and *bromine* act on the fatty oils, producing hydrochloric and hydrobromic acids, and some substitution-compounds containing chlorine or bromine.

When moist chlorine gas is passed into the oils, the temperature rises, but it does not cause explosion. Bromine, on the contrary, acts with violence. The chlorine and bromine products thus obtained are generally of a yellow colour, without taste or smell. They are heavier than water, and possess a greater consistence than the pure oils. Exposed to the air when slightly heated, they become considerably harder.

Iodine also attacks the oils forming substitution-compounds.

The fatty oils are divided into two classes, drying and non-drying oils, which are characterised by their different deportments when exposed to the atmosphere. In close vessels, oils may be preserved unaltered for a very long time, but with contact of the atmosphere they undergo progressive changes. Certain oils thicken and eventually dry into a transparent, yellowish, flexible substance, which forms a skin upon the surface of the oil and retards its further alteration. Such oils are said to be *drying,* or *siccative,* and are on this account used in the preparation of varnishes and painters' colours. Other oils do not dry up, though they become thick, less combustible, and assume an offensive smell. These are the *non-drying oils.* In this state they are called *rancid,* and exhibit an acid reaction, and irritate the fauces when swallowed, in consequence of the presence of a peculiar acid, which may be removed in a great measure by boiling the oil along with water and a little common magnesia for a quarter of an hour, or till it has lost the property of reddening litmus. While oils undergo the above changes, they absorb a quantity of oxygen equal to several times their volume. Saussure found that a layer of nut-oil, one quarter of an inch thick, enclosed along with oxygen gas over the surface of quicksilver in the shade, absorbed only three times its bulk of that gas in the course of eight months; but when exposed to the sun in August, it absorbed 60 volumes additional in the course of ten days. This absorption of oxygen diminished progressively, and stopped altogether at the end of three months, when it had amounted to 145 times the bulk of the oil. No water was generated, but 21·9 volumes of carbonic acid were disengaged, while the oil was transformed in an anomalous manner into a gelatinous mass, which did not stain paper. To a like absorption we may ascribe the elevation of temperature which happens when wool or hemp besmeared with olive or rapeseed oil, is left in a heap: circumstances under which it has frequently taken fire, and caused the destruction of cloth-mills and other buildings and ships.

Although most of the fixed oils and fats are mixtures of two or more of the substances, *oleine, margarine,* and *stearine,* yet there appear to be different modifications of these substances in drying and non-drying oils; for instance, it is only the oleine of the non-drying oils that solidifies when treated with nitrous acid or nitrate of mercury;

and again the difference is shown in the fact of some oils drying completely, while others only thicken and become rancid.

The following is a list of the *Non-drying* Oils and their specific gravity :—

No.	Plants	Oils	Specific gravity
1	Olea Europæa	Olive oil	0·9176
2	Amygdalus communis	Almond oil	0·9180
3	Sesamum orientale	Oil of sesamum	
4	Guilandina mohringa	Oil of behen or ben	
5	Fagus sylvatica	Beech oil	0·9225
6	Sinapis nigra et arvensis	Oil of mustard	0·9160
7	Brassica napus et campestris	Rapeseed oil	0·9136
8	Prunus domestica	Plum-kernel oil	0·9127
9	Theobroma cacao	Butter of cacao	0·8920
10	Cocos nucifera	Cocoa-nut oil	
11	Cocos butyracea vel avoira elais	Palm oil	0·9680
12	Laurus nobilis	Laurel oil	
13	Arachis hypogæa	Ground-nut oil	
14	Valeria Indica	Piney tallow	0·9260
15	Brassica campestris oleifera	Colza oil	0·9136
16	Brassica præcox	Summer rapeseed oil	0·9139
17	Raphanus sativus oleifera	Oil of radish seed	0·9187
18	Prunus cerasus	Cherry-stone oil	0·9239
19	Pyrus malus	Apple-seed oil	
20	Euonymus Europæus	Spindle-tree oil	0·9380
21	Cornus sanguinea	Cornilberry-tree oil	
22	Cyperus esculenta	Oil of the roots of Cyprus grass	0·9180
23	Hyoscyamus niger	Henbane-seed oil	0·9130
24	Æsculus hippocastanum	Horse-chestnut oil	0·9270

The non-drying oils are used as food, for illuminating purposes, and for the greasing of machinery, &c.

The following is a list of the *Drying* Oils :—

No.	Plants	Oils	Specific gravity
1	Linum usitatissimum et perenne	Linseed oil	0·9347
2	Corylus avellana	Nut oil	0·9260
3	Juglans regia		
4	Papaver somniferum	Poppy oil	0·9243
5	Cannabis sativa	Hemp oil	0·9276
6	Cucurbita pepo, et melapepo	Cucumber oil	0·9231
7	Helianthus annuus et perennis	Oil of sunflower	0·9262
8	Ricinus communis	Castor oil	0·9611
9	Nicotiana tabacum et rustica	Tobacco-seed oil	0·9232
10	Vitis vinifera	Grape-seed oil	0·9202
11	Hesperis matronalis	Oil of Julienne	0·9281
12	Myagrum sativa.	Oil of camelina	0·9252
13	Reseda luteola	Oil of weld-seed	0·9358
14	Lepidium sativum	Oil of garden cresses	0·9240
15	Atropa belladonna	Oil of deadly nightshade	0·9250
16	Gossypium Barbadense	Cotton-seed oil	
17	Pinus abies	Pinetop oil	0·9285

The drying oils are used principally for varnishes and for painters' colours. As the quicker they dry the more valuable they are for these purposes, it is desirable still to increase their natural siccative properties as much as possible, and this is generally effected by boiling the oils with litharge (oxide of lead), by which a certain portion of the litharge is dissolved by the oil; but in what way this process tends to increase the siccative properties of the oil is not understood. Chevreul stated that it is not necessary to boil the oils, that a much lower heat acts quite as well. Liebig imagined that the boiling with litharge effects the separation of the mucilaginous and other foreign matters, which tend to protect the oils from the action of the oxygen of the atmosphere, and has proposed a process for their separation without the aid of heat. It consists in shaking the oil, previously triturated with litharge, with a solution of the basic acetate of lead for some time, and afterwards allowing the whole to remain still, when the oil separates, and will then dry in twenty-four hours. The solution of acetate of lead which remains may be again used by converting it into the subacetate. A portion of oxide of lead is dissolved by the oil, and when its presence would be prejudicial, it may be removed by shaking the oil with dilute sulphuric acid. In boiling the oils with acetate of lead and litharge, some painters add about an eighth part of resin, which in that proportion greatly improves the appearance of the paints when dry.

Before describing these oils separately, it is necessary to show the means used for obtaining them from the seeds, &c.

Fat Oil Manufacture.

Olive Oil.—It is the practice of almost all the proprietors in the neighbourhood of Aix, in Provence, to preserve the olives for fifteen days in barns or cellars, till they have undergone a species of fermentation, in order to facilitate the extraction of their oil. If this practice were really prejudicial to the product, as some theorists have said, would not the high reputation and price of the oil of Aix have long ago suffered, and have induced them to change their system of working? In fact, all depends upon the degree of fermentation excited. They must not be allowed to mould in damp places, to lie in heaps, to soften so as to stick to each other, and discharge a reddish liquor, or to become so hot as to raise a thermometer plunged into the mass up to 96° Fahr. In such a case they would afford an acrid nauseous oil, fit only for the woollen or soap manufactories. A slight fermentative action, however, is useful towards separating the oil from mucilage. The olives are then crushed under the stones of an edge-mill, and next put into a screw-press, being enclosed in bulrush-mat bags (*cabas*), laid over each other to the number of eighteen. The oil is run off from the channels of the ground-sill into casks, or into stone cisterns called *pizes*, two-thirds filled with water. The pressure applied to the *cabas* should be slowly graduated.

What comes over first, without heat, is called the virgin oil. The *cabas* being now removed from the press, their contents are shovelled out, mixed with some boiling water, again put in the bags, and pressed anew. The hot water helps to carry off the oil, which is received in other casks or *pizes*. The oil ere long accumulates at the surface, and is skimmed off with large flat ladles; a process which is called *lever l'huile*. When used fresh, this is a very good article, and quite fit for table use, but is apt to get rancid when kept. The subjacent water retains a good deal of oil by the intervention of the mucilage; but by long repose in a large general cistern, called *l'enfer*, it parts with it, and the water is then drawn off from the bottom by a plug-hole: the oil which remains after this is of an inferior quality, and can be used only for factory purposes.

The marc being crushed in a mill, boiled with water, and expressed, yields a still coarser article.

All the oil must be *fined* by keeping in clean tuns, in an apartment, heated to 60° Fahr. at least, for twenty days; after which it is run off into strong casks, which are cooled in a cellar, and then sent into the market.

In Spain the olives are pressed by conical iron rollers elevated above the stage or floor, round which they move on two little margins to prevent the kernel being injured, the oil from which is said to have an unpleasant flavour. Spanish olive-oil, however, is inferior to other kinds, from the circumstance of the time which elapses between the gathering and the grinding of the olives. This is unavoidable on account of the small number of mills, which are not in proportion to the quantity of fruit to be pressed. The olives are therefore allowed to lay in heaps to wait their turn, and consequently often undergo decomposition.

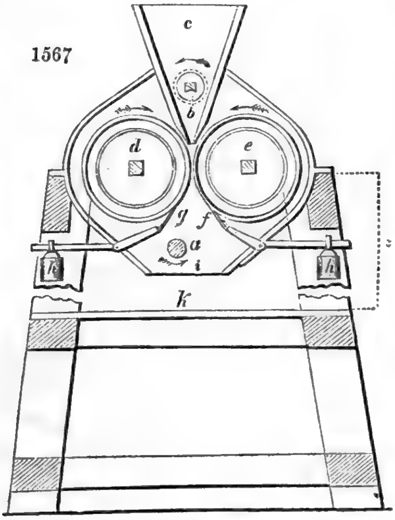
The machinery employed by the Neapolitan peasants in the preparation of the Gallipoli oil is of the rudest kind. The olives are allowed to drop from the trees when ripe, when they are picked up chiefly by women and children, and carried to the mill. The oil, when expressed, is sent in sheep- or goat-skins, carried on mules, to Gallipoli, where it is allowed to clarify in cisterns cut in the rock on which the town is built. From these it is conveyed in skins, to basins near the sea-shore, and from these basins the casks are filled.

According to Sieuve, 100 lbs. of olives yield about 32 lbs. of oil: 21 of which come from the pericarp, 4 from the seed, and 7 from the woody matter of the nut. That obtained from the pericarp is the finest.

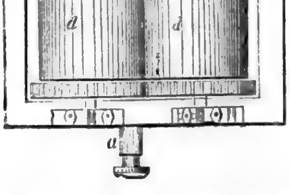
Oil of Almonds is manufactured by agitating the kernels in bags, so as to separate their brown skins, grinding them in a mill, then enclosing them in bags, and squeezing them strongly between a series of cast-iron plates, in a hydraulic press; without heat at first, and then between heated plates. The first oil is the purest, and least apt to become rancid. It should be refined by filtering through porous paper. Next to olive-oil, this species is the most easy to saponify. Bitter almonds being cheaper than the sweet are used in preference for obtaining this oil, and they afford an article equally bland, wholesome, and inodorous. But a strongly-scented oil may be procured, according to M. Planché, by macerating the almonds in hot water, so as to blanch them, then drying them in a stove, and afterwards subjecting them to pressure. The volatile oil of almonds is obtained by distilling the marc or bitter-almond cake along with water.

Linseed, Rapeseed, and Poppyseed Oils.—The seeds of these, and other oleiferous seeds, were formerly treated for the extraction of their oil, by pounding in hard wooden mortars with pestles shod with iron, set in motion by cams driven by a shaft turned with horse- or water-power; then the triturated seed was put into woollen bags which were wrapped up in hair-cloths, and squeezed between upright wedges in press-boxes by the impulsion of vertical rams driven also by a cam mechanism. In the best mills upon the old construction, the cakes obtained by this first wedge pressure, were thrown upon the bed of an edge-mill, ground anew, and subjected to a second pressure, aided by heat now, as in the first case. These mortars and press-boxes constitute what are called Dutch mills. They are still in use both in this country and on the Continent, and are by some persons thought preferable to the hydraulic presses.

1567



1568



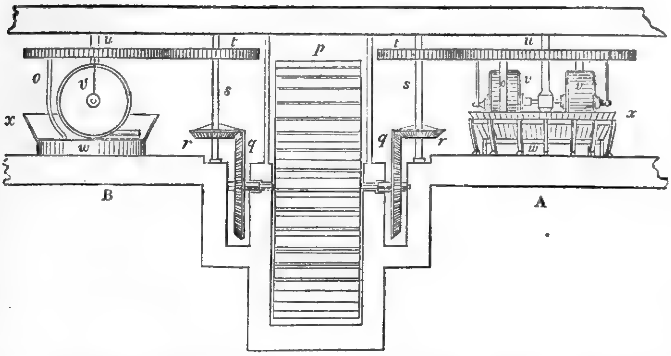
The roller-mill for merely bruising the linseed, &c., previous to grinding it under edge-stones and to heating and crushing it in a Dutch or a hydraulic oil-mill, is represented in *figs.* 1567 and 1568. The iron shaft, *a*, has a winch at each end, with a heavy fly-wheel upon the one of them, when the machine is to be worked by hand. Upon the opposite end is a pulley, with an endless cord which passes round a pulley on the end of the fluted roller, *b*, and thereby drives it. This fluted roller, *b*, lies across the hopper, *c*, and by its agitation causes the seeds to descend equally through the hopper, between the crushing rollers, *d*, *e*. Upon the shaft, *a*, there is also a pinion which works into two toothed wheels on the shafts of the crushing cylinders, *d* and *e*, thus communicating to these cylinders motion in opposite directions. *f*, *g*, are two scraper-blades, which by means of the two weights, *h*, *h*, hanging upon levers, are pressed against the surfaces of the cylinders, and remove any seed-cake from them. The bruised seeds fall through the slit, *i*, of the case, and are received into a chest which stands upon the board, *k*.

Machines of this kind are now usually driven by steam-power. Hydraulic presses have been of late years introduced into many seed-oil mills in this country; but it is still a matter of dispute whether they or the old Dutch oil-mill, with bags of seed compressed between wedges, driven by cam-stamps, be the preferable; that is, afford the largest product of oil with the same expenditure of capital and power.

This bruising of the seed is merely a preparation for its proper grinding, under a pair of heavy edge-stones, of granite, from 5 to 7 feet in diameter; because unbruised seed is apt to slide away before the vertical rolling-wheel, and thus escape trituration.

The edge-mill, for grinding seeds, is represented in *fig.* 1569. *p* is the water-wheel, which may drive several pairs of horizontal bevel-wheels working in *q*, *q*, and turning the shafts, *s*, *s*; *t*, *t*, two horizontal spur-wheels fixed to the upper part of the vertical shafts, and driving the large wheels, *u*, *u*. To the shafts of these latter wheels are fixed the runners, *v*, *v*, which traverse upon the bed-stone, *w*, *w*; *x*, *x*, are the curbs surrounding the bed-stone, to prevent the seeds from falling off; *o*, is the scraper. Mill A represents a view, and mill B, a section of the bed-stone and curb. Some hoop the stones with an iron rim, but others prefer the rough surface of granite, and dress it from time to time with hammers, as it becomes irregular. These stones make from 30 to 36 revolutions upon their horizontal bed of masonry or iron in a minute. The

1569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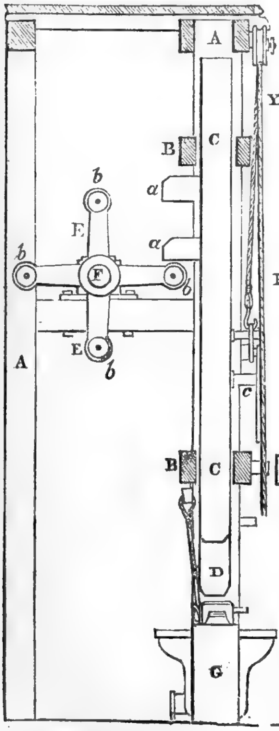
1571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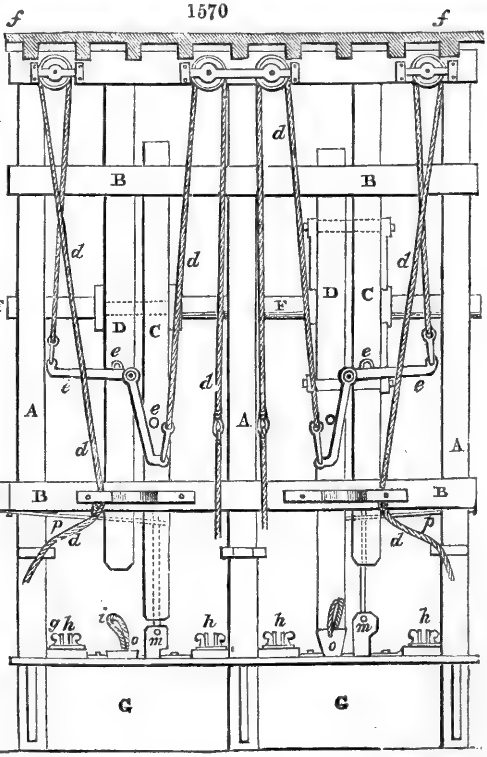
1570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centre of the bed, where it is perforated for the passage of the strong vertical shaft which turns the stones, is enclosed by a circular box of cast iron, firmly bolted to the bed-stone, and furnished with a cover. This box serves to prevent any seeds or powder getting into the step or socket, and obstructing the movement. The circumference of the mill-bed is formed of an upright rim of oak-plank, bound with iron. There is a rectangular notch left in the edge of the bed and corresponding part of the rim, which is usually closed with a slide-plate, and is opened only at the end of the operation, to let the pasty seed-cake be turned out by the oblique arm of the bottom scraper. The two parallel stones, which are set near each other, and travel round their circular path upon the bed, grind the seeds not merely by their weight, of three tons each, but also by a rubbing motion, or attrition; because their periphery being not conical, but cylindrical, by its rolling upon a plane surface, must at every instant turn round with friction upon their resting-points. Strong cast-iron boxes are bolted upon the centre of the stones, which by means of screw clamps seize firmly the horizontal shafts that traverse and drive them, by passing into a slit-groove the vertical turning-shaft. This groove is lined with strong plates of steel, which wear rapidly by the friction, and need to be frequently renewed.

The following are drawings of the wedge or Dutch seed-crushing machines.

Fig. 1570, front elevation of the wedge seed-crushing machine, or wedge-press. *Fig.* 1571, section in the line X X of *fig.* 1572.

1572

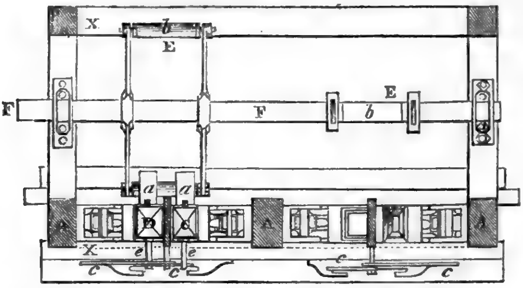


Fig. 1572, horizontal section in the line Y Y, of *fig.* 1571.

A, A, upright guides, or framework of wood.

B, B, side guide-rails.

D, driving stamper of wood, which presses out the oil; C, spring stamper, or relieving wedge, to permit the bag to be taken out when sufficiently pressed. E is the lifting shaft, having rollers, *b*, *b*, *b*, *b*, *fig.* 1571, which lift the stampers by the cams, *a a*, *fig.* 1571. F is the shaft from the power-engine, on which the lifters are fixed.

G is the cast-iron press-box, in which the bags of seed are placed for pressure laterally by the force of the wedge.

o, *figs.* 1569 and 1573; the spring, or relieving wedge.

e, lighter rail; *d*, lifting-rope to ditto.

f, *f*, *f*, flooring overhead.

g, *figs.* 1570, and 1573; the back iron, or end-plate minutely perforated.

h, the horse-hair bags (called hairs), containing the flannel bag, charged with seed; *i*, the dam-block; *m*, the spring wedge.

1573

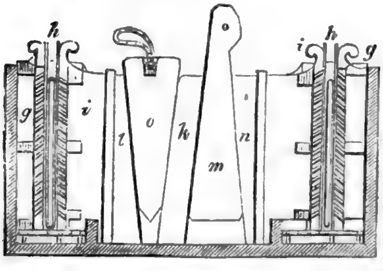


Fig. 1572, A, upright guides; C and D, spring and driving stampers; E, lifting roller; F, lifting-shaft; *a*, *a*, cams of stampers.

Fig. 1573, a view of one set of the wedge-boxes, or presses, supposing the front of them to be removed: *o*, driving wedge; *g*, back iron; *h*, hairs; *i*, dam-block; *k*, speering or oblique block, between the two stampers; *l*, ditto; *n*, ditto; *m*, spring wedge.

The first pressure requires only a dozen blows of the stamper, after which the pouches are left alone for a few minutes till the oil has had time to flow out; in which interval the workmen prepare fresh bags. The former are then unlocked, by making the stamper fall upon the loosening wedge or key, *m*.

The weight of the stampers is usually from 500 to 600 lbs.; and the height from which they fall upon the wedges is from 16 to 21 inches.

Such a mill as that now described can produce a pressure of from 50 to 75 tons upon each cake of the following dimensions:—8 inches in the broader base, 7 inches in the narrower, 18 inches in the height; altogether nearly 140 square inches in surface, and about $\frac{3}{4}$ of an inch thick.

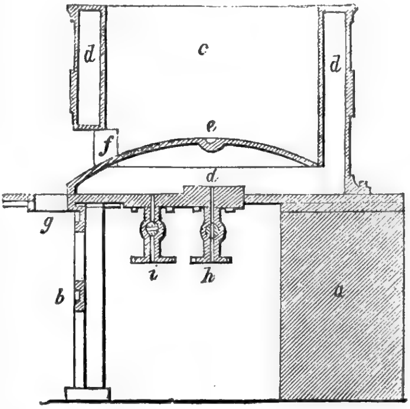
The seeds which have been burst between the rolls, or in the mortars of the Dutch mills, are to be spread as equally as possible, by a shovel, upon the circular path of the edge-stones, and in about half an hour the charge will be sufficiently ground into a paste. This should be put directly into the press, when fine cold-drawn oil is wanted. But in general the paste is heated before being subjected to the pressure. The pressed cake is again thrown under the edge-stones, and, after being ground the second time, should be exposed to a heat of 212° Fahr., in a proper pan, called a steam-kettle, before being subjected to the second and final pressure in the woollen bags and hair-cloths.

Fig. 1574 is a vertical section of the steam-kettle of Hallette, and *fig*. 1575 is a view of the seed-stirrer. *a*, is the wall of masonry, upon which, and the iron pillar *b*, the pan is supported. It is enclosed in a jacket, for admitting steam into the intermediate space *d*, *d*, *d*, at its sides and bottom; *c*, is the middle of the pan in which the shaft of the stirrer is planted upright, resting by its lower end in the step *e*; *f*, is an opening, by which the contents of the pan may be emptied; *g*, is an orifice into which the mouth of the hair or worsted bag is inserted, in order to receive the heated seed, when it is turned out by the rotation of the stirrer and the withdrawal of the plug *f* from the discharge aperture; *h*, is the steam induction pipe; and *i*, the eduction-pipe, which serves also to run off the condensed water.

When, in the course of a few minutes, the bruised seeds are sufficiently heated in the pans, the double door *f* is withdrawn, and they are received in the bags below the aperture *g*. These bags are made of strong twilled woollen cloth, woven on purpose. They are then wrapped in a hair-cloth, lined with leather.

The hydraulic oil-press is generally double: that is, it has two vertical rams placed parallel to each other, so that while one side is under pressure, the other side is being discharged. The bags of heated seed-paste or meal are put into cast-iron cases, which are piled over each other to the number of 6 or 8, upon the press-sill, and subjected to a force of 300 or 400 tons, by pumps worked with a steam-engine. The first pump has usually 2 or $2\frac{1}{2}$ inches diameter for a ram of 10 inches, and the second pump 1 inch. Each side of the press, in a well-going establishment, should work 38 lbs. of seed-flour every 5 minutes. Such a press will do 70 quarters of linseed in the days' work of one week, with the labour of one man at 20*s*. and three boys at 5*s* each; and will require a 12-horse power to work it well, along with the rolls and the edge-stones.

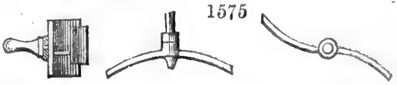
1574



The apparatus for heating the seeds by naked fire, as used in Maudsley and Field's excellent seed-crushing mills, on the wedge or Dutch plan, is represented in the *figs*. 1576, 1577, 1578, and 1579.

Fig. 1576 is an elevation or side view of the fire-place of a naked heater; *fig*. 1577 is a plan, in the line U U of *fig*. 1576. *Fig*. 1578 is an elevation and section parallel to the line V V of *fig*. 1577. *Fig*. 1579 is a plan of the furnace, taken above the grate of the fire-place.

1575



A, fire-place shut at top by the cast-iron plate B; called the fire-plate.

C, iron ring-pan, resting on the plate B, for holding the seeds, which is kept in its place by the pins or bolts *a*.

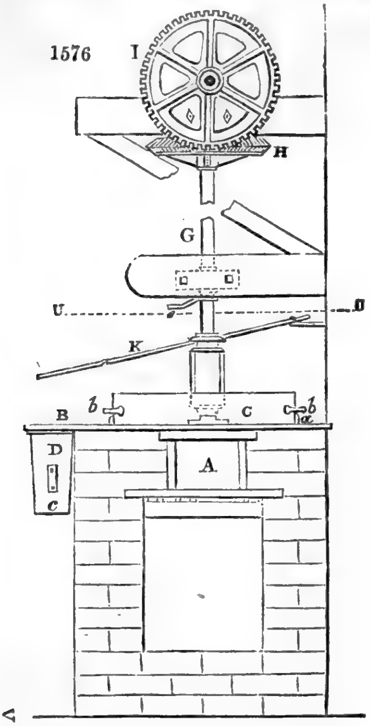
D, funnels, *Britchen*, into which by pulling the ring-case C, by the handles *b b*, the seeds are made to fall, from which they pass into bags suspended to the hooks *c*.

E, *fig*. 1578, the stirrer, which prevents the seeds from being burned by continued contact with the hot plate. It is attached by a turning-joint to the collar F, which turns with the shaft G, and slides up and down upon it. H, a bevel wheel, in gear with the bevel wheel I, and giving motion to the shaft G.

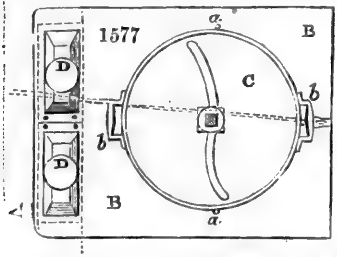
K (*fig.* 1576), a lever for lifting up the agitator or stirrer E. *c*, a catch for holding up the lever K, when it has been raised to a proper height.

A patent was taken out in May 1849, by Messrs. Bessemer and Heywood for a machine to be used for expressing oils from seeds. *Fig.* 1580 is a drawing of it. The bed-plate of framing, *a*, which should be cast in one piece, forms, at a^1, a cistern for the reception of the oily matters which fall therein as they are expressed. At the opposite end of the bed-plate there are formed projections a^2, in which brasses, *b*, are fitted, and with the caps, *c*, form bearings for the crank-shaft, *d*, to turn in. There are also two other projections, a^3, a^3, cast on to the bed-plate, and are provided with caps, *e*, in a similar manner to the caps of plummer-blocks. These caps are for the purpose of retaining firmly in its place the pressing-cylinder, *f*, which should be made of tough gun-metal, and of such thickness as to be capable of withstanding a considerable amount of internal pressure. Within the cylinder, *f*, is fitted a *lining*, which consists of a gun-metal tube, *n*, having a spiral groove, *r*, cut on the outside of it, and presenting the appearance of an ordinary square-threaded screw. At very short intervals all along the spiral groove there are conical holes, *s*, drilled through the tube *n*, and communicating with the interior of it. At n^1 the inside of the tube is enlarged, and is provided with a steel collar, *t*. The opposite end of the tube at n^1 is reduced in diameter, and is provided externally with a steel collar, *u*. A plain

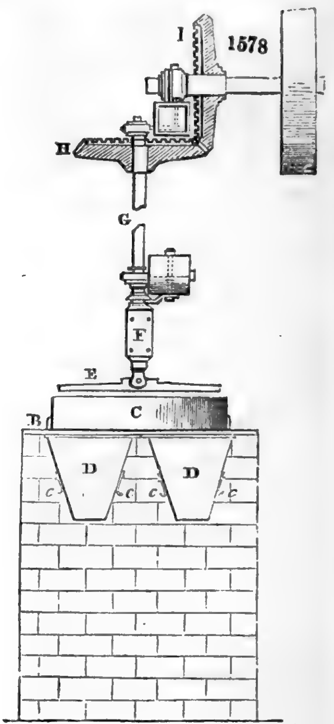
1576



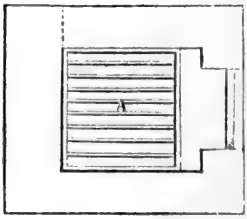
1577



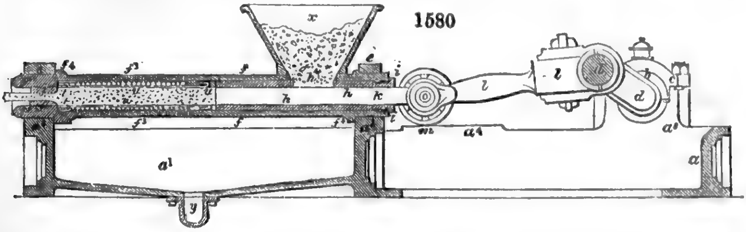
1578



1579



cylindrical bag, with open ends, formed of fustian, hair-cloth, or similarly pervious material, is made of such a diameter as will fit closely to the inside of the tube *n*;

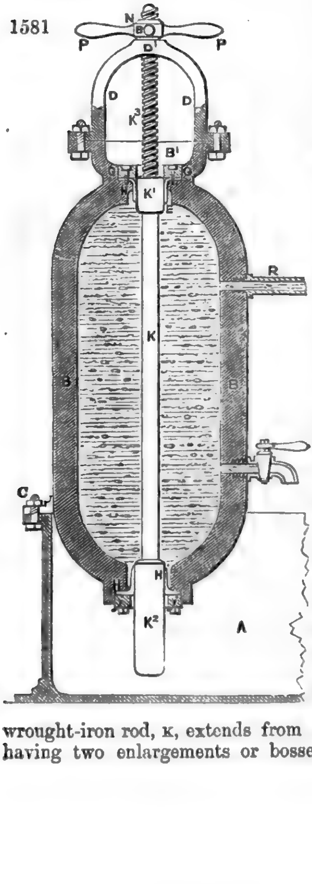

1580

and within this bag is placed a cylinder, of wire gauze or finely-perforated metal. The steel collar *t* is forced into the end of the wire gauze, by which it becomes driven into the recess formed at n^1, and is securely held there by the pressure of the collar *t*. The bag and wire gauze are then tightly stretched over the end, n^2, of the tube, and the collar *u* driven tightly on, by which means the bag and wire gauze are securely held in their places. The lining-tube, *n*, is then put into the pressing-cylinder as far as the shoulder, *g*. A tubular-piece, *h*, is next put in, and brought into contact with the collar *u*, and then the gland, *i*, is screwed home, whereby the lining *n* is firmly retained within the pressing-cylinder. The end of the pressing-cylinder is contracted at f^1, and forms a shoulder for the abutment of the collar *j*, the diameter of the aperture in which regulates the pressure to which the matters under operation are subjected. Within the tube *n* there is fitted a solid plunger, *h*, which receives motion from the crank *d* by means of the connecting-rod *l*, the parallel motion .being obtained by the wheels, *m*, on the cross-head, traversing on the side of the bed-plate at a^4. *x* is a hopper bolted to a flange, f^2, on the pressing-cylinder, and communicating therewith. There is also an opening in the tube *n* at n^1, corresponding with the opening into the hopper, so that any materials placed in the hopper may fall into the tube *n*, when the plunger *k* is withdrawn from beneath the opening. At that part of the pressing-cylinder which is occupied by the 'lining,' there are drilled numerous small holes, f^3, which communicate at various points with the spiral groove in the tube *n*. On the outside of the pressing-cylinder there are formed two collars, f^4, f^4, which abut against the projecting pieces, a^3, and caps, *e*, and cause the pressing-cylinder to be retained firmly in its place. When steam-power is to be employed to give motion to the oil-press, it is preferable to have the crank which is actuated by the steam-piston formed on the end d^1, on the crank-shaft of the oil-press, and placed at such an angle to the crank *d*, that when the crank *d* is pushing the plunger *k* to the end of its stroke, the steam-piston will be at the half-stroke, whereby the motive-power applied will be the greatest at the time that the press offers the most resistance; and the steam-piston also, when passing its dead points, will have to overcome the friction of the machinery only, as the plunger, *k*, will be in the middle of its back-stroke. When any other motive-power is applied to turn the crank *d*, it will be necessary to put a fly-wheel on the shaft d^1, as also such cog-wheels as will be necessary to connect it with the first mover. When this apparatus is to be employed in expressing linseed-oil, the seed, after having been ground and treated in the way now commonly practised, is put into the hopper, and, motion being transmitted to the crank in the manner before described, the plunger *k* will commence a reciprocating movement in the tube *n* of the pressing-cylinder. Each time that it recedes in the direction of the crank it will move from under the opening in the hopper, and allow a portion of the seed to fall into the tube, while the reverse motion of the plunger will drive it towards the open end of the cylinder, its passage being much retarded by the friction against the sides of the tube-lining, but chiefly by the contraction of the escape-aperture through the collar *j*, which will produce a considerable amount of resistance, and consequently the plunger will have to exert an amount of pressure upon the seed in proportion as the escape-aperture is made larger or smaller. The collar, *j*, is made moveable, and, by withdrawing the plunger entirely from the tube, it can be exchanged at any time for another having a larger or smaller opening. The lining may at any time be removed from the cylinder, and the worn parts removed when found requisite. The action of the plunger is somewhat like that of the plunger of an hydraulic press-pump, the seeds being pumped in at one end of the pressing-cylinder, and allowed to escape at the other, while the whole of the interior of the pressing-cylinder that contains seed is lined with hair-cloth or other suitable pervious material, and, that it may be protected from injury, is covered with wire gauze or finely-perforated metal. The bag is thus completely defended from within, while it is supported at every part by the tube *n*, on the outside, and is thus subjected to very little wear, and to no risk of bursting. The expressed oil, passing through the wire gauze and bag, finds its way through a perforation into the spiral channel *r*, and from thence it finds ready egress by the perforations f^3 in the pressing-cylinder, and, as it falls, is received by the cistern a^1, from which it can be drawn by the pipe *y*.

Two or more presses may be used side by side, actuated either by one crank-throw or by separate throws upon one shaft, placed with reference to each other in such manner as greatly to equalise the amount of resistance throughout the revolution of the crank-shaft. Although the one here described is a cylindrical pressing-plunger, an angular section may be given to the pressing vessel and plunger, and may of course be used to express oils from any seeds containing them. In the drawing no method is shown for heating the seed-cake to be subjected to pressure therein; but, as it is known to be desirable to heat some matters from which oil is to be expressed, the following method is described:—

When heat is to be applied during the process of pressing, it is desirable to make the pressing-cylinder of somewhat larger diameter, and of greater length, and to divide the cistern a^1 into two separate compartments, over both of which the pressing-cylinder is to extend; a strong wrought-iron tube is to enter the open end of the pressing-cylinder, and to extend about half-way to the hopper, where it terminates in a solid pointed end; this tube is to occupy the centre of the pressing-cylinder, and will consequently leave an annular space around it, which will be occupied by the seed, meal, or other matters under operation. Steam is let into this iron tube, and its temperature thereby raised to any desired point. The end of the tube which extends beyond the pressing-cylinder is to be securely attached to a bracket projecting from the bed-plate, so that it may be firmly held in its position, notwithstanding the force exerted against the pointed end of it. The effect of this arrangement will be that, as the seed, meal, &c., fall into the pressing-cylinder, and are pushed forward by the plunger, they will give out a portion of their oil in that state known as *cold-drawn*, which will fall into the first compartment of the cistern a^1. The further progress of the meal along the pressing-cylinder will bring it in contact with the pointed end of the heating-tube; here it will have to divide itself, and pass along the annular space between the heating-tube and the lining, and, being thus spread into a thin cylindrical layer around the tube, it will readily absorb heat therefrom, when a second portion of oil will be given out, and received by the second compartment of the cistern; and thus will the operations of cold- and hot-pressing be carried on simultaneously.

1581



Bessemer and Heywood's patent also mentions another machine for the expression of oils from the seeds, &c. by pressure in connection with water, or water rendered slightly alkaline. A sectional drawing of it is represented in *fig.* 1581. A is a cast-iron cistern, having semicircular ends, and open on the upper side. At one end of it is fixed a cylindrical vessel, B, with hemispherical ends. The vessel is of considerable strength, and should be capable of withstanding a pressure of 5,000 lbs. to the square inch. It is held in an upright position by a flange, C, formed upon it, and extending around one-half of its circumference. This flange rests upon a similar one formed around the upper side of the cistern, A, and is bolted thereto. At the upper part of the vessel B is formed a sort of basin, B^1, the edge of which supports an arch-shaped piece of iron, D. At the centre of the basin there is an opening into the vessel, and an hydraulic cup-leather, E, is secured within the opening by means of the collar, G. In the bottom of the vessel B there is also an opening, into which is fitted a cup-leather, H, secured in its place by the ring *j*, which is firmly bolted to the vessel B. A strong wrought-iron rod, K, extends from the top of the arch D, down through the vessel B, having two enlargements or bosses, K^1, K^2, formed upon it, which are fitted to the cup-leathers. The upper part of rod K has a screw formed upon it at K^3, which passes through the boss D^1 and enters the boss N, in which a screw-thread is formed. The boss, N, is provided with handles, P, by turning which the rod K may be raised or lowered when required. R is a pipe, through which water may be injected into the vessel A, by a force-pump, such as is generally employed to work hydraulic presses. S is a cock, whereby a portion of the contents of the vessel B may be run off, and the pressure relieved when necessary. The two bosses, K^1 and K^2, being of equal area, whatever pressure may be exerted within the vessel B, it does not tend to raise or lower the rod K; but such pressure, acting on the cup-leathers, will keep the joint tight, and prevent the matters under pressure from leaking out. After a certain quantity of oil or oleaginous matters have been expressed from vegetable or animal substances, the remaining portions which they contain are more difficult to obtain, and we therefore treat the oil, in combination with the substances in which it is contained, in the following manner:—

The aforesaid substances, after coming from the oil-press or mill, are mixed with as much warm water, or water slightly impregnated with alkaline matter, as will reduce them to a semi-fluid state. They are then to be operated on in the apparatus last described. For this purpose the handles P P are turned round, and the boss K^2 withdrawn from its opening, while the boss K^2, which is much longer, will still close the lower aperture. The semi-fluid materials are then put into the basin B^1, and fall from thence into the vessel B; when it is fully charged, the rod K is again lowered into the position shown in the figure. The communication with the hydraulic press-pump is then made by means of a cock attached to the pump, from which the water flows, through the pipe R, into the vessel B, and thus with a few strokes of the pump the whole of the contents of the vessel B will be subjected to the requisite pressure. An interval of a few minutes is then allowed for the combination of the oil and water, and the cock S is then opened, and a small portion of the fluid contents of the vessel allowed to escape into the cistern. The pressure being thus relieved, the handles P P are to be again turned so as to lift the rod K sufficiently high to withdraw the boss K^2 from the lower opening; the contents of the vessel B will then flow out into the cistern A, and the boss K^2, being again lowered so as to close the lower aperture, the refilling of the vessel may take place for another operation. The pressure thus brought upon the mixture of oleaginous matters and water will cause the oil therein contained to mix with the water, and form a milky-looking fluid, from which the oil may be afterwards separated from the water, either by repose in large vessels, or by evaporating the water therefrom by heat. When the oil is to be used for soap-making, and some other purposes, this combination of oil and water may be used without such separation. When seed-oil is thus obtained, the mucilaginous matters assist in combining these fluids. After the materials have been drawn off from the cistern A, and passed through a strainer, the solid portions are to undergo another pressing, in order to displace the remaining portion of their fluid contents. In some cases it will be found advantageous to boil up the milky-looking fluid resulting from the operation last described, in order to coagulate the albuminous portions, and otherwise assist in the purification of the oil.

The quantities of oil produced by the various seeds vary greatly, and also different samples of the same kind of seed.

The following notes of Mr. E. Woolsey, and his remarks upon the subject of seed-crushing, will be valuable:—

'The chief point of difference depends upon the quality of seed employed. Heavy seed will yield most oil; and seed ripened under a hot sun, and where the flax is not gathered too green, is the best. The weight of linseed varies from 48 lbs. to 52 lbs. per imperial bushel; probably a very fair average is 49 lbs., or 392 lbs. per imperial quarter. I inspected one of the seed-crusher's books, and the average of 15 trials of a quarter each of different seeds in the season averaged 14½ gallons of 7½ lbs. each; say, 109 lbs. of oil per quarter. The crusher, who uses only the hydraulic press, and one pressing, informed me that

Archangel seed will yield from . . .	15 to 16	gals.	(of 7⅛ lbs. each).
Best Odessa	18 and even 19	,,	,,
Good crushing seed	15½	,,	,,
Low seed, such as weighs 48 lbs. per bushel .	13½	,,	,,

'The average of the seed he has worked, which he represents to be of an inferior quality, for the sake of its cheapness, yields 14½ gallons per quarter. I had some American seed which weighed 52¼ lbs. per imperial bushel, ground and pressed under my own observation, and it gave me 111 lbs. of oil; that is to say, 418 lbs. of seed gave 111 lbs. of oil = 26$\frac{56}{100}$ per cent. A friend of mine, who is a London crusher, told me the oil varied according to the seed from 14 to 17 gallons; and when you consider the relative value of seeds, and remember that *oil* and *cake* from any kind of seed is of the *same value*, it will be apparent that the yield is very different; for example,

July 25, 1836, prices of seed,	East India linseed worth	52*s*. per quarter.
	Petersburg linseed	48*s*. to 52*s*. „
	Odessa	52*s*. „

The difference of 4*s*. must be paid for in the quantity of oil which at 38*s*. 6*d*. per cwt. (the then price) requires about 11½ lbs. more oil expressed to pay for the difference in the market value of the linseed. Another London crusher informed me that East India linseed will produce 17 gallons, and he seemed to think that that was the extreme quantity that could be expressed from *any seed.* The average of last year's Russian seed should be about 14 gallons; Sicilian seed, 16 gallons.

Place	Engine-power	Hydraulic presses	Stampers	Rollers	Edge-stones	Kettles	Work done,—reduced to an hour	Number of pressings
France	10 horse-ower	1 hydraulic, 200 tons	5 light stampers	1 pair rolls	1 pr. edge-stones	5 table kettles small size heated by steam	1 English quarter per working hour	2 pressings.
London	20 horse-power	1 hydraulic, 800 tons	13 light stampers	1 pair rolls	2 pr. edge-stones	8 table kettles small size heated by fire	2 English quarters per working hour	2 ditto.
London	12 horse-power, but the engine is used also for other work	none	9 light stampers	2 pair rolls, used also for other purposes	2 pr. edge-stones, used also for other purposes	4 table kettles small size heated by fire	⅞ English quarter per working hour	2 ditto.
Hull .	18 horse-engine, old construction	none	3 very heavy stampers	1 pair rolls	1 pr. edge-stones	3 double case large size steam kettles	1¼ English quarter per working hour	1 ditto.
Ditto .	22 horse-engine	none	6 very heavy stampers	2 pair rolls	2 pr. edge-stones	6 double case large size steam kettles	Not known	1 ditto.

'*Rape-seed*—I have not turned my attention to the quantity of oil extracted from this seed; but a French crusher (M. Geremboret), on whom, I think, one may place considerable dependence, told me, that

3½ lbs.	of best Cambray rape-seed yielded	1 lb. of oil.
3¾ „	common rape-seed	1 „
4¼ „	„ poppy-seed	1 „

'Rape-seed yields from 52 lbs. to 56 lbs. per imperial bushel.'

The following Table shows the quantity of oils obtained from some seeds, fruits, &c.:—

100 parts of each	Oil per cent.	100 parts of each	Oil per cent.
Walnuts	40 to 70	Wild mustard seed	30
Castor-oil seeds	62	Camelina seed	28
Hazel nuts	60	Weld seed	29 to 36
Garden cress seed	56 to 58	Gourd seed	25
Sweet almonds	40 to 54	Lemon seed	25
Bitter almonds	28 to 46	Onocardium acanthe, or bear's foot	25
Poppy seeds	56 to 63	Hemp seed	14 to 25
Oily radish seed	50	Linseed	11 to 22
Sesamum (jugoline)	50	Black mustard seed	15
Lime-tree seeds	48	Beech mast	15 to 17
Cabbage seed	30 to 39	Sunflower seeds	15
White mustard	36 to 38	Stramonium, or thornapple, seeds	15
Rape, colewort, and Swedish turnip seeds	33·5	Grape-stones	14 to 22
Plum kernels	33·3	Horse-chestnuts	1·2 to 8
Colza seed	36 to 40	St. Julian plum	18
Rape seed	30 to 36		
Euphorbium (spurge seed)	30		

To obtain the above proportions of oil, the fruits must be all of good quality, deprived of their pods, coats, or *involucra*, and of all the parts destitute of oil.

Purification of Oils.—As the oils are obtained from the mills they generally contain some albuminous and mucilaginous matter, and some other impurities which require to be removed in order to render the oil perfectly clear and fit for burning, &c. Several processes have been proposed for this purpose, but the one most generally used is that known as Thénard's process.

Although concentrated sulphuric acid acts so strongly on the oils, it is found that, when added only in small quantities, it attacks principally the impurities first. Thénard's process consists in adding gradually 1 or 2 per cent. of sulphuric acid to the oil, previously heated to 100°, and well mixing them by constant agitation. To effect this the process may be carried on in a barrel fixed on an axis and kept revolving, or in a barrel which is itself immoveable, but having fixed on its axis a moveable fan. After the action of the acid is complete, which is known by the oil, after 24 hours' rest, appearing as a clear liquid, holding flocculent matter in suspension, there is added to it a quantity of water, heated to 140°, equal to about two-thirds of the oil; this mixture is well agitated until it acquires a milky appearance. It is then allowed to settle, when, after a few days, the clarified oil will rise to the surface, while the flocculent matter will have fallen to the bottom of the acid liquid. The oil may then be drawn off, but requires to be filtered to make it perfectly clear. The filtration is always a difficult matter, and is conducted in various ways. It is sometimes placed in tubs, in the bottom of which there are conical holes filled with cotton, but the holes become speedily choked with solid matters. Another and more speedy process is by the means of a displacing-funnel, the apertures in the diaphragm being stopped with cotton.

Several patents have been taken out for the purification of oils; some passing hot air through the oil while at the same time exposed to the action of light; others, passing steam through the oil.

Cogan's process is a combination of the latter with Thénard's. He operates upon about 100 gallons of oil, and for this quantity he uses about 10 lbs. of sulphuric acid, which he dilutes previously with an equal bulk of water. This acid mixture is added to the oil, placed in a suitable vessel, in three parts, the oil being well stirred for about an hour between each addition. It is then stirred for 2 or 3 hours, in order to ensure a perfect mixture, and thus let every particle of the oil be acted on by the acid. It then has assumed a very dark colour. After being allowed to stand for 12 hours, it is transferred to a copper boiler, in the bottom of which are holes, through which steam is admitted, and, passing in a finely-divided state through the oil, raises it to the temperature of 212°. This steam process is carried on for 6 or 7 hours; the oil is then transferred to a cooler, having the shape of an inverted cone, terminating in a short pipe, provided with a stop-cock, inserted in its side a little distance from the bottom. After being allowed to stand till the liquids are separated, which generally takes about 12 hours, the acid liquor is drawn off through the pipe at the bottom, and the clear oil by the stop-cock in the side of the cooler; all below this tap is generally turbid, and is clarified by subsidence, or mixed with the next portion of oil.

Sometimes an infusion of nut-galls is used to separate the impurities, the tannic acid contained in which renders the impurities less soluble; the infusion is well mixed with the oil by agitation, and, after separating the two liquids, the oil is deprived of any tannic acid it may have retained, by treating it with acetate of lead, or sulphate of zinc. When the oil is to be used for machinery it must be dried by treatment with freshly-calcined sulphate of lime, or carbonate of soda.

General Remarks on the Non-drying Oils.

Olive Oil.—Few vegetables have been so repeatedly noticed and so enthusiastically described by the ancient writers as the olive tree. The *preserved* or *pickled olives* are the green, unripe fruit deprived of part of their bitterness by soaking them in water, and then preserved in an aromatised solution of salt. There are several varieties met with in commerce, but the most common are the *small French* or *Provence olive* and the *large Spanish olive.* When ripe the fruit abounds in a bland fixed oil, which is an unctuous fluid, of a pale yellow or greenish yellow colour, with scarcely any smell and a bland and mild taste. In cold weather it deposits white fatty globules (a combination of oleine and margarine). Pure olive oil has less tendency to become rancid than most other fixed oils, but the second qualities rapidly become rancid, owing probably to some foreign matters. It is not a drying oil, and is less apt to thicken by exposure to the air, and for this reason is preferred for greasing delicate machinery and clock-work. Brande described a process for preparing it for these latter purposes. The oil is subjected to cold, when it principally solidifies; the portion, however, which still remains liquid is poured off from the solid portion. A piece of sheet-lead, or some shot, are then placed in it, and it is exposed in a corked phial to the action of sunshine. A white matter gradually separates, after which the oil becomes clear and colourless, and is fit for use. Some oil prepared by this process kept its consistence very well for four or five years while in a stoppered bottle, but when exposed to the atmosphere it began to thicken, and did not answer so well as was expected by the watchmaker who tried it, from its appearance before exposure to the air.

The principal object in the process appears to be to get as pure oleine as possible, but the purer the oleine the more likely is it to become thick. According to Kerwych, oleine of singular beauty may be obtained by mixing two parts of olive oil with one part of caustic soda-lye, and macerating the mixture for twenty-four hours with frequent agitation. Weak alcohol must then be poured into it, to dissolve the margarine soap, whereby the oleine, which remains unsaponified, is separated, and floats on the surface of the liquid. This being drawn off, a fresh quantity of spirit is added, till the separation of the oleine be complete.

It has a slightly yellowish tint, which may be removed by digesting with a little animal charcoal in a warm place for twenty-four hours. By subsequent filtration, the oleine is obtained limpid and colourless, and of such quality that it does not thicken with the greatest cold, nor does it affect either iron or copper instruments immersed in it. There are four different kinds of olive oil known in the districts where it is prepared:—1. *Virgin* oil; 2. *Ordinary* oil (*huile ordinaire*); 3, Oil of the *infernal regions* (*huile d'enfer*); 4. Oil prepared by *fermentation.*

1. *Virgin oil.*—In the district Montpellier they apply the term *virgin oil* to that which spontaneously separates from the paste of crushed olives. This oil is not met with in commerce, being all used by the inhabitants of the district, either as an emollient remedy, or for oiling the works of watches. In the district of Aix they give the name *virgin oil* to that which is first obtained from the olives ground to a paste in a mill, and submitted to a slight pressure two or three days after collecting the fruit. Thus, there is no virgin oil brought from Montpellier, but a good deal of it is brought from Aix.

2. *Ordinary oil.*—In the district of Montpellier, this oil is prepared by pressing the olives, previously crushed and mixed with boiling water. At Aix, the *ordinary oil* is made from the olives which have been used for obtaining the *virgin oil.* The paste, which has been previously pressed, is broken up, a certain quantity of boiling water is poured over it, and it is then again submitted to the press. By this second expression, in which more pressure is applied than in the previous one, an oil is obtained somewhat inferior in quality to the *virgin oil.* The oil is separated from the water in a few hours after the operation.

3. *Oil of the infernal regions* (*huile d'enfer*).—The water which has been employed in the preceding operation is, in some districts, conducted into large reservoirs, called the *infernal regions,* where it is left for many days. During this period, any oil that might have remained mixed with the water separates, and collects on the surface. This oil being very inferior in quality, is only fit for burning in lamps, for which it answers very well. It is sometimes called *lamp oil.*

4. *Fermented oil* (*huile fermentée*).—This is obtained in the two above-named districts, by leaving the fresh olives in heaps for some time, and pouring boiling water over them before pressing the oil. But this method is very seldom put in practice, for the olives during the fermentation lose their peculiar flavour, become much heated, and acquire a musty taste, which is communicated to the oil.

The fruity flavour of the oil depends upon the quality of the olives from which it has been pressed, and not upon the method adopted in its preparation.

When olive oil is mixed with *nitrous acid* or *nitrate of mercury,* it solidifies after some time, and forms a solid fat, of a light yellow colour, which is called *elaidine.* It is the oleine of the oil that is affected, and appears to undergo a molecular change, for the *elaidine* is said to have the same ultimate composition as oleine itself.

Olive oil is used as food and in salads, hence it is often called *salad oil.*

Oil of Almonds.—The tree (*Amygdalus communis*) which yields the almond is a native of Syria and Barbary, but is now abundant throughout the south of Europe, and grows even in England, though here the fruit seldom ripens. The oil is obtained by expression from the bitter or sweet almonds, but most generally from the former, from the fact of their being cheaper, and the residual cake being more valuable, yielding by distillation with water the *essential oil of almonds*; when the presence of water is carefully avoided, the oil obtained from them is quite as good as that obtained from the sweet almonds; but when water is present with the almonds, as would be the case if they were deprived of their skins by maceration in water, the oil would possess a more or less acrid taste. The average produce is from 48 to 52 lbs. from 1 cwt. of almonds (*Pereira*). When recently expressed it is turbid, but by rest and filtration becomes perfectly transparent. It possesses generally a slight yellow colour, which becomes considerably paler by exposure to sunshine. It has a mild bland taste, and little or no odour. It is less easily congealed by cold than olive oil. It speedily becomes rancid, and should be kept in well-stoppered bottles. It is soluble in 25 parts of cold alcohol, and in 6 parts of boiling alcohol, and mixes in all proportions with ether. It is used for the same purposes as olive oil, in medicine, &c.; it is nutritious, but difficult of digestion; it is often used mixed with gum or yolk-of-egg as an emulsion.

Almond oil is sometimes adulterated with olive oil, poppy, and teel oil; and some commercial samples of oil seem to be only olive, mixed with a little almond oil.

Teel Oil, or *Oil of Sesamum.*—The seeds which yield this oil are obtained from the *Sesamum orientale*, and are much esteemed in South Carolina, where they are called *oily grain*, and are made into soups and puddings, like rice. The fresh seeds yield a warm pungent oil, which loses its pungency after a year or two, and is then used for salad: it is often mixed with olive oil for soaps, &c.

Oil of Behen or Ben.—This oil is obtained by expression from the seeds of a plant (*Moringa aptera*) indigenous to Arabia and Syria, and cultivated in the West Indies.

Beech Oil.—The nut of the *Fagus sylvatica* yields two kinds of oil, one a turbid oil, and the other a clear oil, slightly yellow, and very thick; it is used in France in cooking, also for illuminating purposes; and the poor of Silesia use it instead of butter.

Oil of Mustard.—The seeds of the white mustard (*Sinapis alba*) yield about 36 per cent. of a yellow fatty oil, that does not solidify by cold. The seeds of the *Sinapis nigra* yield about 18 per cent. of a similar oil.

Rape-seed Oil is expressed from the seeds of various kinds of *Brassica*; the seeds are used when quite dry, being often submitted to heat to coagulate the albumen. The oil requires considerable purification before it is fit for use. There are various methods of purifying the oil. Thénard's process, before mentioned, serves well; Dr. Rudolph Wagner found a solution of chloride of zinc an advantageous substitute for sulphuric acid in the clarification of the oil; Deutsch recommends subjecting the oil to heat until it begins to decompose, and then keeping it in a gentle state of ebullition for a few hours; a scum forms and separates, and, after a few days' rest, the oil is fit for use. Warburton agitates the oil with a certain quantity of a solution of caustic soda, which dissolves the impurities; these separating with the small quantity of soap formed, the oil is afterwards washed with water. English rape-seed yields the best oil; it is used for illuminating, for the manufacture of soap, for oiling woollen stuffs in the process of manufacture, in the preparation of leather, and for lubricating machinery.

Butter of Cacao is prepared from the cacao-nut, the seed of the *Theobroma cacao.*

Plum-kernel Oil.—An oil expressed from the kernel of the *Prunus domestica*, resembling the oil of sweet almonds.

The *Cocoa-nut oil* of commerce is obtained from the kernel of the nut of the *Cocos nucifera*, &c. It is a white solid, possessing a peculiar odour and a mild taste. It is composed principally of a peculiar fat, *cocinine*, and a small quantity of oleine; it speedily becomes rancid. It is employed in the manufacture of candles and soap; it makes a good marine soap that will lather with sea-water; in Ceylon it is used as a pomatum. There is another oil expressed from the bark of the same trees, and used by the Cingalese as an ointment in cutaneous diseases.

Laurel Oil, known also as oil of Bag, is obtained from the berries of the *Laurus nobilis*. See Laurel Oil.

Ground-Nut Oil.—This is obtained from the fruit of the *ground-nut* plant (*Arachis hypogæa*). According to Dr. Buchner this plant belongs to the *Leguminosæ*, and the fruit is a netted yellowish-grey pod, of from 1 to 3 inches long, and 4 to 9 lines thick, in which are contained two or three brownish-red ovate seeds, of the size of a small hazel-nut. Their parenchyma is white, very nutritious and oily; on which account the *Arachis*, which is indigenous to the tropical parts of America, has been transplanted to Asia and Africa, and even to the south of Europe, and is in that climate frequently cultivated and employed for the manufacture of the oil. The oily seeds possess a sweet taste, somewhat like that of haricot beans, and are used in tropical climates partly raw, and partly prepared into a sort of chocolate, which, however, is not equal to that prepared from cacao. The oil is employed for the same purposes as olive oil. It is of a somewhat greenish colour; and has a specific gravity of 0·9163 at 60° Fahr.

Colza Oil. See Colza.

Piney Tallow.—This is prepared from the fruit of the *Vateria Indica*, a tree which grows in Malabar. It is obtained by boiling the fruit with water, and collecting the fat which rises to the surface. It is white, greasy to the touch, and of an agreeable odour. Its fusing-point is at about 95°; its specific gravity at 59° is 0·926, and at 95°, 0·8965. It answers well for the manufacture of soap and candles; but is little known in this country.

Spindle-tree Oil.—The oil of the spindle-tree (*Euonymus Europæus*), is yellowish, rather thick, with the odour of colza oil, of a bitter and acrid taste. It is solid at 5° Fahr.

Butter of Nutmegs.—This is commonly known in the shops as *expressed oil of mace*, and is prepared by beating the nutmegs to a paste, placing them in a bag and exposing them to steam, and afterwards pressing between heated plates. It is imported in oblong cakes (covered by some leaves), which have the shape of common bricks, only smaller. It is of an orange colour, firm consistence, fragrant odour, like that of nutmegs. The genuine article may be known by being soluble in four times its weight of boiling alcohol, or half that quantity of boiling ether. Its principal use is in medicine. It must not be confounded with *essential oil of mace.*

THE DRYING OILS.

Linseed Oil.—The oil is obtained by expression from the seeds of the common flax (*Linum usitatissimum*), either with or without the aid of heat; the latter, being known as cold-drawn linseed oil, is better than that expressed by heat.

Linseed oil is easily saponified, yielding a mixture of oleate and margarate of the alkali, and a large quantity of glycerine.

It is acted on rapidly by nitric acid, producing margaric acid, pimelic acid, and some oxalic acid.

Chlorine and bromine act on it, yielding thick, coloured products: when linseed oil is heated in a retort it gives off, before entering into ebullition, large quantities of white vapours, which condense to a limpid, colourless oil, possessing the odour of new bread. As soon as the ebullition commences these vapours cease; the oil froths up, and at length there is left a thick gelatinous residue, very much resembling caoutchouc.

The principal use of linseed oil is in making paints and varnishes. It attracts oxygen rapidly from the air and solidifies, and this property is what renders it so valuable for these purposes: it is the most useful of all the drying oils. The small quantities of vegetable-albumen and mucilage which the oil naturally contains appear, according to Liebig, to impair to a certain extent its drying qualities, and the real object which is obtained by boiling these oils with litharge, or acetate of lead and litharge, is the removal of these substances; the oil then being brought more directly in contact with the oxygen of the atmosphere, dries up more rapidly. It was previously thought that some of the litharge was reduced to metallic lead, oxidising at the same time some of the linoleine; but Liebig's opinion seems to be more likely to be correct. The boiling of the oil requires some little care. A few hundredths of litharge is added to the oil, or some use acetate of lead and litharge, and, as before stated, about an eighth part of resin; this is boiled with the oil, the scum removed as it forms, and, when the oil has acquired a reddish colour, the source of heat is removed, and the oil allowed to clarify by repose. Liebig thinks heat is not necessary, and his process for treating the drying oils, in order to increase their siccative properties, has already been mentioned. According to MM. E. Barruel and Jean, the resinification of the drying oils may be effected by the smallest quantities of certain substances, which would act in the manner of ferments. The borate of manganese acts in this way; a thousandth part of this salt being sufficient to determine the rapid desiccation of these oils.

Linseed oil is used in the manufacture of printer's ink. Being heated in a vessel until it takes fire, it is allowed to burn some time, then it is tightly covered; and subsequently mixed with about one-sixth of its weight of lamp-black.

The thin, gummed silks receive the last of their many layers with boiled linseed-oil; it is also used for leather-varnishes and for oil-cloths.

The residue, after the expression of the oil from the seeds, is called oil-cake, and is sold for feeding cattle; that obtained from the English linseed is the best.

Walnut Oil.—This is obtained by expression from the ordinary walnuts deprived previously of their skin, which are the produce of a tree (*Juglans regia*) which is a native of Persia, but cultivated in this country for the sake of the nuts.

When recently prepared it is of a greenish colour, but by age becomes a pale yellow. According to M. Saussure its specific gravity at 53·6° Fahr. is 0·9283, and at 201° Fahr., 0·871. It has no odour, but an agreeable taste. At 5° Fahr. it thickens, and at 17·5° Fahr. it forms a whitish mass. The nuts yield about 50 per cent. of oil. It dries still more rapidly even than the linseed oil. It is principally used for paints and varnishes, and from its lighter colour, it is often used for white paints.

Oil of the Hazel-nut.—This is extracted from the seeds of the *Corylus avellana*, which yield about 60 per cent. of the oil. It is liquid, has only a slight colour, no odour, and a mild taste. Its specific gravity at 59° Fahr. is 0·9242; at 14° Fahr. it solidifies.

Poppy Oil.—This is expressed from the seeds of the common poppy (*Papaver somniferum*), which grows wild in some parts of England, It is cultivated in very large quantities in Hindostan, Persia, Asia Minor, and Egypt, for the sake of the opium which is obtained from the capsules. It is cultivated in Europe for the capsules, which are used in medicine, and for the oil extracted from the seeds. The oil is obtained by expression from the seeds, which do not possess any of the narcotic properties of the capsules. These seeds are sold for birds, under the name of *maw-seed.*

It is used sometimes for burning; and, after treatment with litharge or subacetate of lead, is used for paints.

Hemp-seed Oil.—The seed of the common hemp (*Cannabis sativa*) yield, by expression, from 14 to 15 per cent. of their weight of a fixed oil. It is obtained principally from Russia, but the native places of the plant are Persia, Caucasus, and hills in the north of India. The seeds are small, ash-coloured, shining bodies. They are demulcent and oleaginous, but possessing none of the narcotic properties of the plant. They are employed for feeding cage-birds, and it has been stated that the plumage of certain birds, as the bullfinch and goldfinch, becomes changed to black by the prolonged use of this seed. When fresh this oil is greenish, but becomes yellow by age; it has a disagreeable odour, and insipid taste. It is sometimes used for illuminating-purposes, but, being a drying oil, it forms a thick varnish, and thus clogs the wick; it is used also in making soft soap, and in paints. When boiled with litharge or subacetate of lead it forms a good varnish.

Sunflower Oil.—The seeds of the sunflower (*Helianthus annuus*) yield about 15 per cent. of a limpid oil, having a clear yellow colour. It has an agreeable odour, and mawkish taste. Its specific gravity at 60° is 0·9263; at 9° Fahr. it becomes solid. It is sometimes employed as food, as well as for illuminating-purposes, and for making soap.

Castor Oil.—The castor-oil plant has been known from the remotest ages. Caillaud found the seeds of it in some Egyptian sarcophagi, supposed to have been at least 4,000 years old. Some people imagine it is the same plant that is called the *gourd* in Scripture. It was called *κρότων* by the Greeks, and *ricinus* by the Romans. It is a native of India, where it sometimes grows to a considerable size, and lives several years. There appear to be several species of the *Ricinus*; the officinal is the *Ricinus communis*, or *Palma Christi.*

The seeds are oval, somewhat compressed, about 4 lines long, 3 lines broad, and 1½ line thick; externally they are pale grey, but marbled with yellowish-brown spots and stripes.

The oil may be obtained from the seeds by expression, by boiling with water, or by the agency of alcohol. Nearly all that is consumed in England is obtained by expression. See CASTOR OIL.

Castor oil is said to be adulterated sometimes with croton oil, to increase its activity, this is a dangerous sophistication; it is also mixed with some cheap fixed oils. The latter adulteration has been said to be detected by the solubility of castor oil in alcohol; but, unfortunately, castor oil may contain as much as 33 per cent. of another fixed oil, and yet be soluble in its own volume of alcohol (*Pereira*), this oil possessing the property of rendering other oils soluble in spirit.

Grape-seed Oil.—The grape-stones (*Vitis vinifera*) yield about 11 per cent. of their weight of a fixed oil, which is, when fresh, of a clear yellow colour, but becomes brown by age. It has an insipid taste, and little or no odour. Its specific gravity at 60° Fahr· is 0·9202; at 3° Fahr. it becomes solid. It is not of much value for illuminating purposes; but in some southern localities it is used for food.

Oil of the Pine and Fir trees.—In the Black Forest, in Germany, an oil is extracted from the cleaned seeds of the *Pinus picea* and *P. abies.* It is limpid, of a golden-yellow colour, and resembles in smell and taste the oil of turpentine. Its specific gravity at 60° Fahr. is 0·93; it only congeals at −22° Fahr. It is very fluid, and dries rapidly.

Oil of Camelina.—This is extracted from the seeds of the *Myagrum sativum.* It is of a clear yellow colour, with but little smell or taste, and dries rapidly by exposure to the air.

The Oil of Belladonna-seeds.—This oil is extracted in Wurtemberg from the seeds of the *Atropa belladonna*, and is there used for lighting and cooking. It is limpid, of a golden-yellow colour, insipid taste, and no odour.

Oil of Tobacco-seeds.—The seeds of the *Nicotiana tabacum* yield about 31 per cent. of their weight of a drying oil, which is limpid, of a greenish-yellow colour, and no odour. It does not possess any of the narcotic principles of the plant.

Cotton-seed Oil.—Many attempts have been made to render fit for use the oil obtained from the seeds of the cotton-plant (*Gossypium Barbadense*, &c.), as immense quantities of these seeds are allowed to rot, or used only as manure upon the cotton-lands of the south of the United States of America. When obtained by expression, the oil which runs from the press is of a very dark red colour. It, however, deposits some of the colouring-matter by standing, as well as a portion of semi-fluid fat; and in cold weather this is precipitated in large quantities; and only partially redissolves again by increase of temperature. The great obstacle to the use of the oil thus obtained is its colour, which appears to be derived from a dark, resinous substance, presenting itself in small dots throughout the seed. These may readily be seen by examining a section of the seeds with a lens, or even with the naked eye (*Mr. Wayne, Pharmaceutical Journal*, xvi. 335). In bleaching the oil loses from 10 to 15 per cent., a portion of which may be again recovered and used for making soap, for which purpose cotton-seed oil seems best fitted. It is a drying oil, and consequently not well fitted for machinery; and, when burnt, rapidly clogs the wick. A very good soap for common purposes is made from it in New Orleans.

Mr. Wayne also states, 'that the oil, to be made profitably, should either be manufactured in the vicinity of the cotton-plantation, as the seeds, from the attached fibre, are bulky, and the cost of transportation great; or the seed should be hulled at the spot, and shipped to the place where it is to be pressed in that condition, as it requires three or four bushels of seed in the wool to produce one bushel of hulled seed ready for the mill. The hull and attached fibre are useful for paper stock; and the cake, left after the extraction of the oil, is nearly as valuable a food for cattle as that of linseed.

'It appears that boiling the crushed seeds with water yields a very bland, light coloured oil.

'The desire to bring this oil into use still exists, for a sample of it was sent a few months since from a merchant in America to a friend of mine to see if he could succeed in purifying it, which no doubt will ultimately be effected by some one.'

Croton Oil.—This oil is obtained from the seeds of the *Croton Tiglium* by expression, or by the use of alcohol. It is a most violent purgative, and its only use is in medicine. See Pereira's *Materia Medica.*

Animal Oils.

The only oils which will be mentioned here are lard oil, tallow oil, and neat's-foot oil. The solid fats will be described under their different heads. See Stearine.

Lard Oil.—This oil is now imported largely from America; and is obtained by subjecting ordinary hog's-lard to pressure, when the liquid part separates, while the lard itself becomes much harder. It is employed for greasing wool, for which purpose it answers very well, and may be obtained at a low price. According to Braconnet, lard yields 0·62 of its weight of this oil, which is nearly colourless. Specific gravity 0·915 (*Chevreul*). 100 parts of boiling alcohol dissolve 123 parts of it.

Tallow Oil.—This oil is obtained from tallow by pressure. The tallow is melted, and, when separated from the ordinary impurities by subsidence, is poured into vessels, and allowed to cool slowly to about 80°, when the stearine separates in granules, which may be separated from the liquid part by straining through flannel, and is then pressed, when it yields a fresh portion of liquid oil. It is employed in the manufacture of some of the best soaps.

Neat's-foot Oil.—After the hair and hoofs have been removed from the feet of oxen, they yield, when boiled with water, a peculiar fatty matter, which is known under the name of *neat's-foot oil*; after standing, it deposits some solid fat, which is separated by filtration: the oil then does not congeal at 32°, and is not liable to become rancid. It is often mixed with other oils. This oil is used for various purposes, especially, owing to its remaining liquid at so low a temperature, for oiling church clocks, which require, in consequence of the cold they are exposed to, an oil which is not liable to solidify.

Fish Oils.

Although the whale is not, truly speaking, a fish, the oil obtained from it is classed among the fish oils; and those which will be described here are, whale oil, porpoise oil, seal oil, and cod-liver oil. The three former are all known under the name *train oil.*

Whale Oil.—The capture of the whales is a large commercial undertaking; many well-manned ships, and fitted out at a great expense, proceed every year from England, Holland, France, and other nations, into the Arctic zone in search of these animals, and especially the Greenland species (*Balæna mysticetus*). This valuable animal has produced to Britain 700,000*l.* in one year, and one cargo has been known to be worth 11,000*l.* The Greenland whale inhabits the polar seas; its length is from 60 to 70 feet when full-grown. When the whales are captured they are secured alongside the ship, and the process of *flensing* commences. The men, having shoes armed with long iron spikes to maintain their footing, get down on the huge and slippery carcass, and, with very long knives and sharp spades, make parallel cuts through the blubber, from the head to the tail. A band of fat, however, is left around the neck, called the *kent,* to which hooks and ropes are attached for the purpose of shifting round the carcass. The long parallel strips are divided across into portions, weighing about half a ton each; and, being separated from the flesh beneath, are hoisted on board, chopped into pieces, and put into casks. During the homeward voyage the animal matters, &c. attached to the blubber, undergo decomposition to a certain extent, while there is at the same time a peculiar fat formed, which is a compound of glycerine and *phocenic acid,* and which imparts the disagreeable odour peculiar to train oil. Dumas has shown that this acid is identical with valerianic acid. After the decomposition of the blubber, the oil runs from it easily, and the whole is put into casks with perforated bottoms, placed over tanks for receiving the oil. The oil is heated to about 212°, to facilitate the separation of the impurities; and, in order to further purify it, some use a solution of tannin, to precipitate the gelatine present; others use different metallic salts, as acetate of lead. On the western coast of Ireland the whale is sometimes captured, and yields a large quantity of very good oil, superior to sperm oil for illuminating purposes. The sperm whale (*Physeta macrocephalus*) does not yield so much oil as the Greenland whale, but yields considerably more of the valuable substance *spermaceti.*

Train oil is of a brownish colour, with a disagreeable odour. It is used for lighting, in the manufacture of soaps, and in the preparation of leather.

Seal Oil.—The seal-fishery of Newfoundland has now become the most important part of the trade of that colony. Although, perhaps, not so extensive a staple as the cod-fishery, yet, when capital and time employed, &c., are taken into consideration, it is the most profitable business of that colony.

A quarter of a century ago, there were only about 50 vessels, varying from 30 to 60 tons burthen, engaged in this branch of trade; but it has since been gradually increasing, until upwards of 400 vessels are engaged in the trade.

The vessels engaged in this business are from 75 to 200 tons burthen. Those lately added to the sailing fleet, and which are now considered of the most suitable sizes, range from 130 to 160 tons. Vessels of this size carry from 40 to 50 men. The season of embarking for this voyage is from the 1st to the 15th of March. The voyage seldom exceeds two months, and is often performed in two or three weeks. Several vessels make two voyages in the season, and some perform the third voyage within the space of two months and a half.

The seals frequenting the coast of Newfoundland are supposed to whelp their young in the months of January and February; this they do upon pans and fields of ice, on the coast, and to the northward of Labrador. This ice—or the 'whelping ice,' as it is termed—from the currents and prevailing northerly and north-east winds, trends towards the east and north-east coast of Newfoundland, and is always to be found on some part of the coast after the middle of March, before which time the seals are too young to be profitable.

The young seal does not take to the water until it is three months old. They are often discovered in such numbers within a day's sail of the port, that three or four days will suffice to load a vessel with the *pelts,* which consist of the skin and fat attached, this being taken off while the animal is warm; the carcass, being of no value, is left on the ice. The young seals are accompanied by the old ones, who take to the water on the approach of danger. When the ice is jammed, and there is no open water, large numbers of the old seals are shot. The young seals are easily captured; they offer no resistance, and a slight stroke of a bat on the head readily despatches them. When the pelts are taken on board, sufficient time is allowed for them to cool on deck. They are then stowed away in bulk in the hold, and in this stage they reach the market of St. John's and other ports in the island. Five-sevenths of the whole catch reach the St. John's market. A thousand seals are considered as a remunerating number: but the majority of the vessels return with upwards of 3,000, many with

5,000 and 6,000, and some with as many as 7,000, 8,000, and 9,000. Seals were formerly sold by tale; they are now all sold by weight—that is, so much per cwt. for fat and skin.

The principal species captured are the hood and harp seal. The bulk of the catch consists of the young hood and harp in nearly equal proportions. The best and most productive seal taken is the young harp. There are generally four different qualities in a cargo of seals, namely—the young harp, young hood, old harp and bedlamer (the latter is the year-old hood), and the old hood. There is a difference of 2*s.* per cwt. in the value of each denomination.

The first operation after landing and weighing is the skinning, or separating the fat from the skin; this is speedily done, for an expert skinner will skin from 300 to 400 young pelts in a day. After being dry-salted in bulk for about a month, the skins are sufficiently cured for shipment, the chief market for them being Great Britain. The fat is then cut up, and put into the seal-vats.

The seal-vat consists of what are termed the crib and pan. The crib is a strong wooden erection, from 20 to 30 feet square, and 20 to 25 feet in height. It is firmly secured with iron clamps, and the interstices between the upright posts are filled in with small round poles. It has a strong timber floor, capable of sustaining 300 or 400 tons. The crib stands in a strong wooden pan, 3 or 4 feet larger than the square of the crib, so as to catch all the drippings. The pan is about 3 feet deep, and tightly caulked. A small quantity of water is kept on the bottom of the pan, for the double purpose of saving the oil in case of a leak, and for purifying it from the blood and any other animal matter of superior gravity. The oil made by this process is all cold-drawn: no artificial heat is applied in any way, which accounts for the unpleasant smell of seal oil. When the vats begin to run, the oil drops from the crib upon the water in the pan; and as it accumulates it is casked off, and ready for shipment. The first running, which is caused by compression from its own weight, begins about the 10th of May, and will continue to yield what is termed *pale seal oil,* from two to three months, until from 50 to 70 per cent. of the quantity is drawn off, according to the season, or in proportion to the quantity of old seal fat being put into the vats. From being tougher, this is not acted upon by compression, nor does it yield its oil until decomposition takes place; and hence it does not, by this process, produce pale seal oil. The first drawings from the vats are much freer from smell than the latter. As decomposition takes place, the colour changes to straw, becoming every day, as the season advances, darker and darker, and stinking worse and worse, until it finally runs brown oil. As this running slackens, it then becomes necessary to turn over what remains in the vats. The crib being generally divided into nine apartments or pounds, this operation is performed by first emptying one of the pounds, and dispersing the contents over the others, and then filling and emptying them alternately, until the entire residue, by this time a complete mass of putrefaction, is turned over. By this process a further running of brown oil is obtained. The remains are then finally boiled out in large iron pots, which, during the whole season, are kept in pretty constant requisition for boiling out the cuttings and clippings of the skinning and other parts of the pelts, which it is not found advisable to put into the vats. The produce of this, and the remains of the vats, are what is termed the 'boiled seal oil.' These operations occupy about six months, and terminate towards the end of September.

During the months of July, August, and September, the smell and effluvia from the vats and boiling operation are almost insufferable. The healthy situation of St. John's, from its proximity to the sea and the high and frequent local winds, is doubtless the cause of preventing much sickness at this season of the year. The men more immediately employed about the seal-vats have a healthy and vigorous appearance.

Some improvement has taken place since the great fire of 1846, when all the seal-vats in the town were destroyed. Many of the manufacturers have erected their new vats on the south or opposite side of the harbour; but there still remain sufficient vestiges of the seal trade to cause a summer residence in the town of St. John's anything but desirable. Even the country for several miles around St. John's affords no protection from these horrible stenches. The animal remains from the vats, and the offal from the cod-fish are found to be such a valuable manure, that they are readily purchased by the farmers in the neighbourhood; and from whatever quarter the wind blows, the pedestrian in his rural walk has little chance of breathing a genial atmosphere.

Mr. S. G. Archibald directed his attention to some mode of improving the manufacture of the seal oil. The result of several experiments upon the different qualities of seal's fat satisfied him that the whole produce of the fishery, if taken while the material is fresh, as it generally arrives in the market, and subjected to a process of artificial heat, was capable of yielding, not only a uniform quality of oil, but the oil so produced was much better in quality than the best prepared by the old process, and free from the unpleasant smell common to all seal oil. His subsequent experiments resulted in the invention of a steam apparatus for rendering seal and other oils, which has been found to answer an admirable purpose, and for which he received letters-patent under the Great Seal of the Island of Newfoundland.

The advantage of this process must be manifest, when it is understood that twelve hours suffice to *render* the oil, which by the old process requires about six months; that a uniform quality of oil is produced superior to the best *pale* by the old process, and free from smell; that a considerable percentage is saved in the yield, and what is termed *pale seal*, produced from the old as well as from the young seal. Besides, if this process were universally adopted, the manufacturing season would cease by the 31st of May, and the community would be saved from the annoyance attending the old process.

Porpoise Oil.—This oil very much resembles whale oil.

Cod-liver Oil.—This oil is obtained principally from the livers of the common cod (*Callarias; Gadus Morrhua*), previously called *Asellus major*, and also from some allied species, as the Dorse (*Gadus callarias*), the Coal Fish (*Merlangus carbonarius*), the Burbot (*Lota vulgaris*), the Ling (*Lota molva*), and the Torsk (*Brosimus vulgaris*). The mode of preparing this oil varies in different countries; that found in the London market is the produce of Newfoundland, where, according to Pennant, it is thus procured:—Some spruce boughs are pressed hard down into a half tub, having a hole through the bottom; upon these the livers are placed, and the whole exposed to the sun. As the livers become decomposed the oil runs from them, and is caught in a vessel placed under the tub.

De Jongh describes three kinds of cod-liver oil: the *pale*, *pale brown*, and *brown*.

Pale cod-liver Oil.—This is golden-yellow; without disagreeable odour; not bitter, but leaves a peculiar acrid, fishy taste in the mouth; has a slight acid reaction; sp. gr. 0·923 at 63·5° Fahr. Cold alcohol dissolves from 2·5 to 2·7 per cent. of the oil; hot alcohol from 3·5 to 4·5 per cent. It is soluble in ether in all proportions.

Pale brown cod-liver Oil.—Colour of Malaga wine; odour not disagreeable; bitterish, leaving an acrid, fishy taste in the throat; reacts feebly as an acid; sp. gr. 0·924 at 63·5° Fahr. A little more soluble in alcohol than the *pale oil*.

Dark brown cod-liver Oil.—This is dark brown, and by transmitted light is greenish; it possesses a disagreeable odour, and a bitter and empyreumatic taste, which remains some time in the fauces; it is slightly acid; sp. gr. 0·929 at 63·5° Fahr. Still more soluble in alcohol than the *pale brown oil*.

Cod-liver oil is principally used in medicine; for a fuller description of it, see Pereira's *Materia Medica*.

Dugong Oil.—This oil has been used instead of cod-liver oil, principally in Australia; but as very little, *if any*, real Dugong oil has reached England, it will merely require a short notice here. The Dugong is an herbivorous animal, belonging to the order of *Sirenia*, and is found on the northern coast of Australia, in the Red Sea, the Persian Gulf, and also in the Indian seas. It has received different names by different nations. In the Indian seas it is sometimes found of a large size, from 18 to 20 feet long; but in Australia it is seldom caught of more than 12 or 14 feet. In its general form it resembles the common whale. Its favourite haunts are the mouths of rivers and straits between proximate islands, where the depth of water is but trifling (3 or 4 fathoms), and where, at the bottom, grows a luxuriant pasturage of submarine algæ and fuci, on which it feeds. The oil is obtained by skinning the animal and then boiling down the 'speck.' It was used by the natives of Australia originally for burning.

Adulteration of the Oils.—Owing to the large quantities of oil of various kinds which are now used, and their difference in price, many are the adulterations which take place. Thus the best olive oil for the table is mixed with oils of less value, as poppy oil, sesame oil, or ground-nut oil; and the second olive oil, for the manufactures, with colza oil; and again colza oil itself mixed with poppy, camelina, and linseed oils, but more frequently with whale oil, &c. Various means have been proposed to discover these admixtures. M. Lefebvre proposed to take advantage of the difference of density of the several oils, but this is a very insufficient test, as many of the oils have nearly the same density.

M. Poutet treats the oil to be tested with one-twelfth of its weight of a solution of nitrate of mercury, containing hyponitric acid; this latter substance converts the oleine of most of the non-drying oils into a solid substance, *elaidine*. By this means pure olive oil will become perfectly solid after an hour or two, whereas poppy oil and the drying oils in general remain perfectly liquid; it would therefore result that olive oil adulterated with these latter oils would be prevented from solidifying more or less, according to the quantity of these oils present. An improvement in this process

General Table of Reactions.

Oils	Caustic soda. Sp. gr. 1·340	Sulphuric acid. Sp. gr. 1·475	Sulphuric acid. Sp. gr. 1·530	Sulphuric acid. Sp. gr. 1·635	Nitric acid. Sp. gr. 1·180	Nitric acid. Sp. gr. 1·220	Nitric acid. Sp. gr. 1·33	+Caustic soda. Sp. gr. 1·340	Phosphoric acid. Syrupy	Sulphuric acid + Nitric acid	Aqua regia	+Caustic soda. Sp. gr. 1·340
Olive . .	Slight yellow	Green tinge	Greenish-white	Light green	Greenish	Greenish	Greenish	Fluid white mass	Slight green	Orange-yellow	..	Fluid white mass.
Gallipoli . .	Ditto	Ditto	Grey	Brown	Ditto	Ditto	Ditto	Fibrous ditto	Ditto	Dark brown	..	Fibrous yellowish-white mass.
India nut .	Thick and white	..	Dirty white	Light brown	..	..	..	Ditto	..	Orange-white	..	Fibrous white mass.
Pale rapeseed .	Dirty yellowish-white	..	Pink	Brown	..	..	..	Fluid ditto	..	Dark brown	..	Fibrous yellowish-white mass.
Poppy . .	Ditto	..	Dirty white	..	..	Orange-yellow	Red	Light red fluid mass	..	Slight yellow	..	Fluid intense rose-coloured mass.
French nut .	Ditto	Brownish	Grey	Brown	Yellow	Red	Dark red	Fibrous red mass	Brown-yellow	Dark brown	Yellow	Fibrous orange mass.
Sesame . .	Ditto	Green tinge	Greenish dirty white	..	Orange-yellow	Ditto	Ditto	Fluid red mass, with brown liquor underneath	..	Green becoming intense red	Ditto	Fluid orange mass with brown liquor beneath.
Castor . .	White	..	Dirty white	..	..	..	..	Fibrous white mass	..	Brownish-red	..	Fibrous pale rose-coloured mass.
Hempseed .	Thick brownish-yellow	Intense green	Intense green	Intense green	Dirty green	Greenish dirty brown	Greenish dirty brown	Fibrous light brown mass	Green	Green becoming black	Green	Fibrous light brown mass.
Linseed . .	Fluid yellow	Green	Dirty green	Green	Yellow	Yellow	Green becoming brown	Fluid yellow mass	Brown yellow-green	Ditto	Greenish-yellow	Fluid orange mass.
Lard . .	Pinkish-white	Dirty white	Dirty white	Light brown	..	..	Very slight yellow	Fluid mass	..	Brown	..	Fluid pink mass.
Neat's-foot .	Dirty yellowish-white	Yellow tinge	Brownish dirty white	Brown	Light yellow	Light yellow	Light brown	Fibrous white mass	..	Dark brown	Slight yellow	Fibrous brownish-yellow mass.
Sperm . .	Dark red	Light red	Red	Intense brown	Slight yellow	Ditto	Red	Fluid mass	Dark red	Ditto	Ditto	Fluid orange-yellow mass.
Seal. . .	Ditto	Ditto	Ditto	Ditto	Pink	Light red	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Cod-liver. .	Ditto	Purple	Purple	Ditto	..	..	Ditto	Ditto	Ditto	Ditto	Yellow	Ditto

is to substitute nitric acid, saturated with hyponitric acid, for the nitrate-of-mercury solution. The sample to be tested is shaken with two or three per cent. of this acid, and then placed in a cool place, and the moment of solidification noticed. It is always better also to treat a sample of oil of known purity to the same test at the same time, and compare the results. If the sample tested be pure, it will solidify quite as quickly as the sample which serves for comparison. One hundredth of poppy oil present will delay the solidification 40 minutes (*Gerhardt*), and of course the greater the quantity of admixture, the more will it be delayed.

M. Maumène takes advantage of the greater amount of heat given out by the admixture of concentrated sulphuric acid with the drying oils than takes place with olive oil under the same circumstances. MM. Heydenreich and Penot employ sulphuric acid also to detect the different oils, but they notice the peculiar colorations which take place on contact of the concentrated acid with the different kinds of oils. Their test is thus performed:—one drop of concentrated sulphuric acid is added to 8 or 10 drops of the oil, placed on a piece of white glass, resting on a sheet of white paper; different colorations appear, which they state are characteristic of the different oils; thus olive oil gives a deep yellow tint, becoming greenish by degrees; colza oil, a greenish blue; poppy oil, a pale yellow tint, with a dirty grey outline; hempseed oil, a very deep emerald tint; and linseed oil becomes brownish red, passing directly into blackish brown, &c. These reactions are, however, uncertain; the age of the oil, mode of extraction, &c., altering them greatly.

Marchand states that a mixture of poppy oil and olive oil, when thus treated, developes, after a certain time, on their outline, a series of colours, rose, lilac, then blue, and more or less violet-coloured, according to the proportion of poppy oil, while pure olive oil becomes of a dirty grey, then yellow and brown.

As the means of detecting the various fraudulent admixtures is of great commercial value, the late F. C. Calvert's valuable paper on the adulteration of oils is referred to. —*Pharmaceutical Journal*, xiii. 356.

The accompanying table of reactions (see opposite page) will be found very useful.

Of the more important oils we imported in the years from 1868 to 1873 inclusive, as follows:—

		1868	1869	1870	1871	1872	1873
Fish oil	tuns	13,991	15,264	19,706	24,679	18,719	15,069
Palm oil	cwts.	960,059	814,520	868,270	1,047,882	1,006,497	1,017,947
Cocoa-nut oil	,,	194,752	264,365	198,602	190,492	438,883	266,798
Olive oil	tuns	17,585	28,240	23,202	88,281	24,025	35,121
Seed oil	,,	23,292	19,920	13,429	10,354	20,084	17,593
Turpentine oil	cwts.	108,897	119,893	89,178	178,615	220,292	234,177

OILS, VOLATILE, ETHEREOUS, OR ESSENTIAL. The volatile oils occur in every part of odoriferous plants, whose aroma they diffuse by their exhalation; but in different organs of different species. Certain plants, such as thyme and the scented *Labiatæ* in general, contain volatile oil in all their parts; but others contain it only in the blossoms, the seeds, the leaves, the root, or the bark. It sometimes happens that different parts of the same plant contain different oils; the orange, for example, furnishes three different oils, one of which resides in the flowers, another in the leaves, and a third in the skin or epidermis of the fruit. The quantity of oil varies not only with the species, but also in the same plant with the soil, and especially with the climate; thus, in hot countries it is generated most profusely. In several plants the volatile oil is contained in peculiar orders of vessels, which confine it so closely that it does not escape in the drying, nor is dissipated by keeping the plants for many years. In other species, and particularly in flowers, it is formed continually upon their surface, and flies off at the moment of its formation.

Volatile oils are usually obtained by distillation. For this purpose the plant is introduced into a still, water is poured upon it, and, heat being applied, the oil is volatilised by the aid of the watery vapour at the temperature of 212°, though when alone it would probably not distil over unless the heat were 100° more.

There are a few essential oils which may be obtained by expression from the substances which contain them; such as the oils of lemons and bergamot, found in the pellicle of the ripe fruits of the *Citrus limonum* and *C. bergamia*, or the lemon and the bergamot. The oil comes out in this case, with the juice of the peel, and collects upon its surface.

For collecting the oils of odoriferous flowers which have no peculiar organs for imprisoning them, and therefore speedily let them exhale, such as violets, jasmine, tuberose, and hyacinth, another process must be resorted to. See PERFUMERY.

Essential oils differ much from each other in their physical properties. Most of them are yellow, others are colourless, red or brown; some again are green, and a few are blue. They have a powerful smell, more or less agreeable, which immediately after their distillation is occasionally a little rank, but becomes less so by keeping. The odour is seldom as pleasant as that of the recent plant. Their taste is acrid, irritating, and heating, or merely aromatic when they are largely diluted with water or other substances. They are not greasy to the touch, like the fat oils, but, on the contrary, make the skin feel rough. They are almost all lighter than water, only a very few falling to the bottom of this liquid; their specific gravity lies between 0·847 and 1·096; the first number denoting the density of oil of citron, and the second that of oil of sassafras. Although styled volatile oils, the tension of their vapour, as well as its specific heat, is much less than that of water. The boiling-point differs in different kinds, but it is usually about 316° or 320° Fahr. Their vapours sometimes render reddened litmus-paper blue, although they contain no ammonia. When distilled by themselves, the volatile oils are partially decomposed; and the gaseous product of the portion decomposed always carry off a little of the oil. When they are mixed with clay or sand, and exposed to a distilling heat, they are in a great measure decomposed; or when they are passed in vapour through a red-hot tube, combustible gases are obtained, and a brilliant porous charcoal is deposited in the tube. On the other hand, they distil readily with water, because the aqueous vapour formed at the surface of the boiling fluid carries along with it the vapour of the oil produced in virtue of the tension which it possesses at the 212th degree Fahr. In the open air the volatile oils burn with a shining flame, which deposits a great deal of soot. The congealing-point of the essential oils varies greatly; some do not solidify till cooled below 32°, others at this point, and some are concrete at the ordinary temperature of the atmosphere.

When exposed to the air the volatile oils change their colour, become darker, and gradually absorb oxygen. This absorption commences whenever they are extracted from the plant containing them; it is at first considerable, and diminishes in rapidity as it goes on. Light contributes powerfully to this action, during which the oil disengages a little carbonic acid, but much less than the oxygen absorbed; no water is formed. The oil turns gradually thicker, loses its smell, and is transformed into a resin, which becomes eventually hard. De Saussure found that oil of lavender, recently distilled, had absorbed, in four winter months, and at a temperature below 54° Fahr., 52 times its volume of oxygen, and had disengaged twice its volume of carbonic acid gas; nor was it yet completely saturated with oxygen. The stearescence of anise-seed oil absorbed at its liquefying temperature, in the space of 2 years, 156 times its volume of oxygen gas, and disengaged 26 times its volume of carbonic acid gas. An oil which has begun to experience such an oxidisement is composed of a resin dissolved in the unaltered oil; and the oil may be separated by distilling the solution along with water. To preserve oils in an unchanged state, they must be put in phials, filled to the top, closed with ground-glass stopples, and placed in the dark.

Volatile oils are little soluble in water, yet enough so as to impart to it by agitation their characteristic smell and taste.

They are soluble in alcohol, and the more so the stronger the spirit is. Some volatile oils, devoid of oxygen, such as the oils of turpentine and citron, are very sparingly soluble in dilute alcohol; while the oils of lavender, pepper, &c. are considerably so. Such combinations form the odoriferous spirits which the perfumers incorrectly call waters, as *lavender water, eau de Cologne, eau de jasmin*, &c. They become turbid by admixture of water, which seizes the alcohol, and separates the volatile oils. Ether also dissolves all the essential oils.

These oils combine with several vegetable acids, such as the acetic, the oxalic, the succinic, the fat acids (stearic, margaric, oleic), the camphoric, and suberic.

With the exception of the oil of cloves, the volatile oils do not combine with the salifiable bases. They have been partially combined with caustic alkali, as in the case of Starkey's soap. This is prepared by triturating recently-fused caustic soda in a mortar, with a little oil of turpentine, added drop by drop, till the mixture has acquired the consistence of soap. The compound is to be dissolved in spirits of wine, filtered and distilled. What remains after the spirit is drawn off, consists of soda combined with a resin formed in the oil during the act of trituration.

The essential oils dissolve all the fat oils, the resins, and the animal fats.

In commerce, these oils are often adulterated with fat oils, resins, or balsam of capivi dissolved in volatile oil. This fraud may be detected by putting a drop of the oil on paper and exposing it to heat. A pure essential oil evaporates without leaving any residuum, whilst an oil mixed with any of the above substances leaves a translucent stain upon the paper. If fat oil be present, it will remain undissolved, on mixing the adulterated essential oil with thrice its volume of spirit of wine of specific gravity 0·840. Resinous matter mixed with volatile oil is easily detected, being left in the alembic after distillation. Oil diluted with spirit of wine forms a milky emulsion on the addition of water; the alcohol is absorbed by the water, and the oil afterwards found on the surface, in a graduated glass tube, will show by its quantity the amount of the adulteration.

Oil of bitter almonds is prepared by exposing the bitter-almond cake, from which he bland oil has been expressed, in a sieve to the vapour of water rising within the still. The steam, as it passes up through the bruised almond *parenchyma*, carries off its volatile oil, and condenses along with it in the worm. The oil which first comes over, and which falls to the bottom of the water, has so pungent and penetrating a smell, that it is more like cyanogen gas than hydrocyanic or prussic acid. This oil has a golden yellow colour; it is heavier than water; when much diluted, it has an agreeable smell, and a bitter burning taste. When exposed to the air, it absorbs oxygen, and lets fall a heap of crystals of benzoic acid. Perfumers formerly employed a great quantity of this oil in scenting their soaps. But nitro-benzole is now used, instead of the essential oil of bitter almonds, in flavouring. See BENZOLE; NITRO-BENZOLE. A similar oil is obtained by distilling the following substances with water: —the leaves of the peach (*Amygdalus Persica*), the leaves of the bay-laurel (*Prunus lauro-cerasus*), and the bruised kernels of cherry- and plum-stones. All these oils contain hydrocyanic acid, which renders them poisonous, and they also generate benzoic acid, by absorbing oxygen on exposure to air.

Oil of anise-seed is extracted by distillation from the 'seeds' of the *Pimpinella anisum,*

Oil of bergamot is extracted by pressure from the rind of the ripe fruit of the *Citrus bergamia.*

Oil of cajeput is prepared in the Moluccas, by distilling the dry leaves of the *Melaleuca cajeputi.* Cajeput is a native word, signifying merely a white tree. This oil is green; it has a burning taste, a strong smell of camphor, turpentine, and savine.

The oil of caraway is extracted from the seeds (cremocarps) of the *Carum carui.*

The oil of cassia, from the *Cinnamomum cassia*, is yellow passing into brown.

The oil of chamomile is extracted by distillation from the flowers of the *Anthemis nobilis.* It has a blue colour when quite fresh, but becomes yellow by exposure; it possesses the peculiar smell of the plant.

Oil of cinnamon is extracted by distillation from the bark of the *Laurus cinnamomum.* It is produced chiefly in Ceylon from the pieces of bark unfit for exportation. It is distilled over with difficulty, and the process is promoted by the addition of salt water, and the use of a low still.

The oil of cloves is extracted from the dried flower-buds of the *Caryophyllus aromaticus.* It is colourless, or yellowish, has a strong smell of the cloves, and a burning taste. It is one of the least volatile oils.

The oil of elder is extracted by distillation from the flowers of the *Sambucus nigra.*

Oil of fennel is extracted by distillation from the seeds of the *Anethum Fœniculum.*

Oil of juniper is obtained by distilling juniper berries along with water. These should be bruised, because their oil is contained in small sacs or reservoirs, which must be laid open before the oil can escape. It is limpid and colourless, or sometimes of a faint greenish yellow colour.

The oil of lavender is extracted from the flowering spike of the *Lavandula vera.*

Oil of lemons is extracted by pressure from the yellow peel of the fruit of the lemon or *Citrus limonum.*

The oil of mace lets fall, after a certain time, a concrete oil under the form of a crystalline crust, called by John *myristicine.*

The oil of nutmegs is extracted chiefly from mace, which is the inner epidermis of these nuts.

The oil of orange-flowers, called *neroli,* is extracted from the fresh flowers of the *Citrus aurantium.* When recently prepared it is yellow; but when exposed for two hours to the rays of the sun, or for a longer time to diffuse daylight, it becomes of a yellowish-red. It is very fluid, lighter than water, and has a most agreeable smell. The aqueous solution, known under the name of orange-flower water, is used as a perfume.

The oil of parsley is extracted from the *Apium Petroselinum.*

The oil of pepper is extracted from the *Piper nigrum.*

The oil of peppermint is extracted from the *Mentha piperita.*

The oil of pimento is extracted from the envelopes of the fruit of the *Eugenia pimenta,* which afford 8 per cent. of it.

The oil of rhodium is extracted from the wood of the *Convolvulus scoparius.*

The oil of roses, called the *attar* or *otto*, is extracted from the petals of the *Rosa centifolia* and *R. sempervirens*.

The oil of rosemary is extracted from the *Rosmarinus officinalis*.

The oil of saffron is extracted from the *stigmata* of the *Crocus sativus*. It is narcotic.

The oil of sassafras is extracted from the woody root of the *Laurus sassafras*.

Oil of savine is extracted from the leaves of the *Juniperus sabina*.

Oil of thyme is obtained from the *Thymus vulgaris*.

Oil of wormwood is distilled from the *Artemisia absinthium*.

Oil of turpentine. See TURPENTINE.

OIL-STONE. A peculiar slate-stone found in Turkey and elsewhere, which forms a better whetstone than any other substance. The finest are found in the interior of Asia Minor, and being imported, are known as Turkey hones or oil-stones.

OLD RED SANDSTONE. A geological formation so called; named by Sedgwick and Murchison, *Devonian*, as portions of the system are peculiarly developed in Devonshire. See SANDSTONE.

OLEATES are saline compounds of oleic acid with the bases.

OLEFIANT GAS is the name originally given to bi-carburetted hydrogen. See CARBURETTED HYDROGEN.

OLEIC ACID. A neutral oil, obtained by saponifying mutton-fat with potash, and decomposing the soap with sulphuric acid. The fat acids are dissolved in hot alcohol; the solution on cooling is expressed, and the operation frequently repeated. Oleic acid is insoluble in water, but soluble in alcohol and ether. Its formula appears to be $C^{36}H^{33}O^{3},HO$ ($\mathbf{C^{18}H^{34}O^{2}}$).

OLEINE, or *Lipyle*. Obtained by boiling tallow in alcohol. It is regarded as an *oleate of oxide of glyceryle*. It constitutes the more fluid portion of oils.

OLEOGRAPH. The name given to a picture printed in oils. It is prepared by a process of block-printing.

OLIBANUM is a gum-resin, used only as incense in Roman Catholic churches.

OLIVE OIL. See OILS.

ONICOLO, or **NICOLO**. A variety of onyx having a ground of deep brown, in which is a band of bluish-white. It is used for cameos, and differs from the ordinary onyx in a certain blending of the two colours.—H. W. B.

ONYX. A mineral belonging to the chalcedonic variety of quartz. It resembles agate, excepting that the colours are arranged in flat horizontal planes. When the layers consist of *sard* and white *chalcedony*, the stone is called *sardonyx*.

These stones were formerly more prized than they are at present, and were frequently cut in cameo and intaglio.

OOLITE. (*Oolith*, Ger. From *ὠόν*, an egg, and *λίθος*, *a stone.*) A geological term. Those varieties of limestone which are composed of an aggregation of small spherical concretions resembling in appearance the roe of a fish, and bound together by a calcareous cement. When first quarried they are generally soft, but harden by exposure to the air and the evaporation of the water.

The particles are generally formed of concentric layers of carbonate of lime arranged round a grain of sand, a fragment of shell, or some organic substance, forming the nucleus around which the calcareous matter has been deposited.

The name Roestone, from the fanciful resemblance of these oolitic concretions to the roe of a fish, has likewise been given to this kind of limestone when the grains are of small sizes; when of comparatively large dimensions, as in some beds of Inferior Oolite in the neighbourhood of Cheltenham, they are distinguished by the name of Peastone or Pisolite (from *πίσον*, *a pea*, and *λίθος*, *stone*).

In geological nomenclature, the term Oolite has a more extended signification, and is applied indiscriminately to the entire accumulation of strata consisting of limestones, marls, clays, and sands, intervening between the Trias or New Red and the Wealden formations, in consequence of the limestones of those deposits frequently possessing an oolitic structure. Of these, Portland stone, Coral Rag, Bath or Great Oolite, and Inferior Oolite are the most important in an economical point of view, owing to their furnishing fine descriptions of freestone, suitable for building and ornamental purposes, both from their tints, which are either white or cream coloured, and the large blocks in which they can be obtained.

The well-known white freestone obtained from Caen in Normandy is an Oolitic limestone belonging to the Bath or Great Oolite formation.

Although the oolite formations constitute the chief repositories of limestones possessing an oolitic structure, they are not confined to those groups of strata, but are met with in other formations, as for instance in some beds of carboniferous or mountain limestone in the neighbourhood of Bristol, as well as very largely in that of Ireland.—H. W. B.

OOLITIC LIMESTONE. Limestones of the Oolitic series of rocks, such as Bath stone, Portland stone, and Caen stone. See LIMESTONE.

OOST, or **OAST.** The provincial name of the stove in which picked hops are dried.

OPAL. An ornamental stone. The following are the more important varieties of the opal:—*The precious opal*, exhibiting a play of rich colours. *Fire opal* or *girasol*, with hyacinth-red and yellow reflections. *Common opal, semi-opal*; non-opalescent varieties. *Hydrophane*; non-transparent, but becoming so by immersion in water. *Cacholong*; nearly opaque, of a bluish-white colour. *Hyalite*; colourless, pellucid, or white. *Opal jasper, wood opal*; and several others. All these are composed of silica in the gelatinising or colloidal state, with more or less water, and occasionally, as accidental admixtures, other bodies in small proportions. By analyses the following results have been obtained as regards the silica:—The precious opal of Hungary contains 92 per cent. of silica; the fire opal of Mexico, 92; the fire opal of Faroe, 88·73; semi-opal of Hanau, 82·75; semi-opal of Kaschau, 92·16; and the cacholong of Faroe, 95·82.

Opal may be regarded as an uncleavable quartz. Its fracture, conchoidal; lustre, vitreous or resinous; colours, white, yellow, red, brown, green, grey; lively play of light. Hardness, 5·5 to 6·5; specific gravity, 2·091. It occurs in small kidney-shaped and stalactitic shapes, and large tuberose concretions. The phenomena of the play of colours in precious opal have not been satisfactorily explained. Haüy attributes the play of colours to the fissures of the interior being filled with films of air, agreeably with the law of Newton's coloured rings. Mohs, however, thinks this would produce iridescence merely. Brewster concludes that it is owing to fissures and cracks in the interior of the mass of a uniform shape.

The precious opal stands high in estimation, and is considered one of the most valuable gems, the size and beauty of the stone and the variety of the colours determining its value. The so-called 'mountain of light,' an Hungarian opal in the Great Exhibition of 1851, weighed 526½ carats, and was estimated at 4,000*l.* sterling.

In Vienna is a precious opal weighing 17 oz.; and it is said a jeweller of Amsterdam offered half a million of florins for it, which was refused.

Hydrophane, or *Oculis mundi*, is a variety of opal without transparency, but acquiring it when immersed in water, or in any transparent fluid.

Hungary has long been the chief locality of precious opal, where it occurs near Kaschau, along with common and semi-opal, in a kind of porphyry. Fine varieties have, however, been discovered in the Faroe Islands; and most beautiful ones, sometimes quite transparent, near Gracios-a-Dios, in the province of Honduras, America. Precious opal has also been recently found in Queensland, and to a less extent in New South Wales. The red and yellow bright coloured varieties of fire opal are found near Zimapan, in Mexico. In modern times, fine opals of moderate bulk have been frequently sold at the price of diamonds of equal size; the Turks being particularly fond of them. The estimation in which opal was held by the ancients is hardly credible. Nonius, the Roman senator, preferred banishment to parting with his favourite opal, which was coveted by Mark Antony. Opal which appears quite red when held against the light, is called *girasol* by the French; a name also given to the sapphire, or corundum asteria, or star-stone.

OPEN-CAST. *A miner's term*, signifying that the mineral is obtained by open workings, and not by mining.

OPERAMETER is the name given to an apparatus invented by Samuel Walker, of Leeds. It consists of a train of toothed wheels and pinions enclosed in a box, having indexes attached to the central arbor, like the hands of a clock, and a dial-plate; whereby the number of rotations of a shaft projecting from the posterior part of the box is shown. If this shaft be connected by any convenient means to the working parts of a gig-mill, shearing-frame, or any other machinery of that kind for dressing cloths, the number of rotations made by the operating-machine will be exhibited by the indexes upon the dial-plate of this apparatus.

A similar clock-work mechanism, called a *counter*, has been for a great many years employed in the cotton-factories, and in the pumping-engines of the Cornish and other mines, to indicate the number of revolutions of the main-shaft of the mill, or of the strokes of the piston. A common pendulum, or spring-clock, is commonly set up alongside of the counter; and sometimes the indexes of both are regulated to go together.

OPIUM is the juice which exudes from incisions made in the heads of ripe poppies (*Papaver somniferum*), rendered concrete by exposure to the air. The best opium which is found in the European markets comes from Asia Minor and Egypt; what is imported from India is reckoned inferior in quality. This is the most valuable of all the vegetable products of the gum-resin family, and very remarkable for the complexity of its chemical composition.

The following list contains most of the varieties of opium known in commerce:—

Smyrna opium, from *Turkey* or the *Levant*.
Constantinople opium.
Egyptian opium.
Trebizond opium, *Persian opium.*
Indian opium. *Benares, Malwa,* and *Patna.*
English opium.
French and German opium.

See Watts's 'Dictionary of Chemistry.'

Our Consul in China, reporting on the opium trade, says that the use and abuse of opium are much exaggerated. Taking the total import into China at 12,800,000 lbs. in the year, what is that for a population numbering about 400,000,000? He states that the use of opium is confined to narrower limits than is generally supposed; and excess in its consumption is the exception, not the rule. To confirmed smokers it becomes a necessity of existence; by others it is regarded as a luxury. Mr. Hughes, British Consul at Hankow, gives the Chinese credit for a growing preference of the native opium on account of its mildness, which makes it easier to give up its use temporarily, or abandon it altogether, without serious effect upon the health. He says the production of native opium is very considerable; and his colleague, M. Blancheton, after a visit to Szechuen, estimates the nett value of all the opium grown in that province at about 35,000,000 taels sycee (the Hankow tael averages a fraction over 6*s.*); but the figures are given as 'anything but certain.' Mr. Morgan, Consul at Tient-sin, thinks there are some grounds for anticipating that the prohibitory edict will be executed more efficiently than others which have preceded it; and Acting-Consul Harvey, at Newchwang, reports that in that province the action of the authorities in enforcing the prohibition of the growth of opium has lessened the production, and raised the price nearly to that of foreign opium.

OPOBALSAM is the balsam of Peru in a dry state. See Balsam of Peru.

OPOPONAX. This is a gum-resin; the dried milky juice which exudes by incision from the root of the parsnip-like plant *Opoponax Chironium*; this plant is found abundantly growing wild in Macedonia and Sicily.

The gum was formerly used in medicine. Referring to the plant, Dioscorides names it *Panax Herculeum*, from Hercules, who was supposed to have discovered it. In his time it was one of the three celebrated panacea or universal medicines; at a later period it was not administered internally, but was in general use in the form of an ointment for the cure of wounds. So recently as fifty years ago it was one of the standard drugs of the apothecary, but then chiefly employed in the form of a plaster.

OPUS ALEXANDRIUM. A mosaic pavement, consisting of geometric figures in black and red tesseræ on a white ground.

ORANGE. A well-known fruit. See Citrus.

ORANGE-CHROME. A subchromate of lead; a fine orange-coloured pigment. which is very durable. See Chromates of Lead.

ORANGE-DYE is given by a mixture of red or yellow dyes in various proportions. Arnotto alone dyes orange; but it is a fugitive colour.

ORCHELLA WEEDS. The cylindrical and flat species of *Roccella* used in the manufacture of *Orchil* or *Archil*, and *Cudbear*, are so called by the makers.

The following list of orchella weeds is given by Pereira:—

Angola orchella, *Roccella fuciformis.*
Madagascar orchella, *R. fuciformis.*
Mauritius orchella.
Canary orchella, *R. tinctoria.*
Cape de Verd orchella, *R. tinctoria.*
Azore orchella, *R. tinctoria.*
Madeira orchella, *R. tinctoria* and *R. fuciformis.*
Lima orchella, large and round, *R. tinctoria.*
Lima orchella, small and flat, *R. fuciformis.*
Cape of Good Hope orchella. *R. hypomecha.*
Barbary orchella, *R. tinctoria.*
Corsican and Sardinian orchella, *R. tinctoria.*

Dr. Pereira says:—'Mr. Harman Visger, of Bristol, informs me that every lichen but the best orchella weed is gone, or rapidly going, out of use; not from deterioration of their quality, for, being allowed to grow, they are finer than ever, but because the Angola weed is so superior in quality, and so low priced and abundant, that the product of a very few other lichens would pay the expense of manufacture.'

In the 'Philosophical Transactions' for 1848, Dr. Stenhouse has a valuable paper on the colouring-matters of the lichens. From it we extract his directions for estimating the colouring-matter in lichens by means of a solution of hypochlorite of lime:—

Any convenient quantity of the orchella weed may be cut into very small pieces, and then macerated with milk of lime, till the colouring-matter is extracted. Three or four macerations are quite sufficient for this purpose, if the lichen has been sufficiently comminuted. The clear liquors should be filtered and mixed together. A solution of bleaching-powder of known strength should then be poured into the lime solution from a graduated alkalimeter. The moment the bleaching-liquor comes in contact with the lime solution of the lichen, a blood-red colour is produced, which disappears in a minute or two, and the liquid has only a deep yellow colour. A new quantity of the bleaching-liquid should then be poured into the lime solution, and the mixture carefully stirred. This operation should be repeated so long as the addition of the hypochlorite of lime causes the production of the red colour, for this shows that the lime solution still contains unoxidised colorific principle. Towards the end of the process, the bleaching-solution should be added by only a few drops at a time, the mixture being carefully stirred between each addition. We have only to note how many measures of the bleaching-liquid have been required to destroy the colouring-matter in the solution, to determine the amount of the colorific principle it contained. Dr. Stenhouse suggests the following method for extracting the colorific principle for transport:—Cut the lichens into small pieces, macerate them in wooden vats with milk of lime, and saturate the solution with either muriatic or acetic acid. The gelatinous principle is then to be collected on cloths and dried by a gentle heat. In this way the whole of the heat can be easily extracted, and the dried extract transported from the most distant localities. See ARCHIL; LICHENS.

ORCHIL. See ARCHIL.

ORCIN is the name of the colouring-principle of several of the lichens. The lichen dried and pulverised is to be exhausted by boiling alcohol. The solution filtered hot lets fall, in the cooling, crystalline flocks, which do not belong to the colouring-matter. The supernatant alcohol is to be distilled off, the residuum is to be evaporated to the consistence of an extract, and triturated with water till this liquid will dissolve no more. The aqueous solution, reduced to the consistence of syrup, and left to itself in a cool place, lets fall, at the end of a few days, long brown brittle needles, which are to be freed by pressure from the mother-water, and dried. That water being treated with animal charcoal, filtered and evaporated, will yield a second crop of crystals. These are orcin. See LICHEN; LITMUS. See also Watts's 'Dictionary of Chemistry.'

ORDEAL BEAN. The Calabar bean; the seeds of *Physostigma venatum*, Balf.

ORE. The natural chemical compound of a metal with some other element, such as oxygen, sulphur, arsenic, &c. These elements have been sometimes termed *mineralisers*; and when metals are found free from them they are called *native* metals, and not *ores*.

OREIDE is the name given by MM. Meurier and Valient, of Paris, to an alloy which has a golden brilliancy. It is composed of copper 100, zinc 17, magnesia 6, sal-ammoniac 3·6, quicklime 1·80, and tartar of commerce 9.

The copper is first melted, and then the other things are added by small portions at a time, skimming, and keeping in fusion for about half an hour.

The oreide, which is a brass, has a fine grain, is malleable, takes a most brilliant polish, and, if it tarnishes, its lustre is restored by acidulated water.

ORELLIN. A yellow colouring-matter contained in arnatto. It is soluble in water, in alcohol, and ether. It dyes alumed goods yellow.

ORES, DRESSING OF. See DRESSING OF ORES.

ORICHALCUM. An old alloy, called also *false silver*.

ORIENTAL EMERALD. The name given to green sapphire.

ORIENTAL TOPAZ. The name given to yellow sapphire.

OR-MOLU. A brass, in which there is less zinc and more copper than in the ordinary brass; the object being to obtain a nearer imitation of gold than ordinary brass affords. In many of its applications the colour is heightened by means of a gold lacquer, but in some cases, and, as we think, with very great advantage, the true colour of the alloy is preserved after it has been properly developed by means of dilute sulphuric acid.

ORPIMENT (Eng. and Fr.; *Operment*, *Rauschgelb*, Ger.; *Yellow sulphide of arsenic*) is found native in many parts of the world, as in Hungary, Turkey, China, &c.; the finest specimens being brought from Persia, in brilliant yellow masses, of a lamellar texture, called 'golden orpiment.'

Native orpiment is the *auripigmentum*, or *paint of gold*, of the ancients. It was so called in allusion to its use and its colour, and also because it was supposed to contain gold. From this term the common name of '*orpiment*,' or '*gold paint*,' has been derived.

In nature it is found most generally in amorphous masses of a bright yellow colour, but sometimes in crystals, which are oblique rhombic prisms; these crystals are flexible, of a yellow colour, and possess a brilliant lustre. See ARSENIC.

Native orpiment has a specific gravity of about 3·48. Orpiment is also prepared artificially, chiefly in Saxony, by subliming in cast-iron cucurbits, surmounted by conical cast-iron capitals, a mixture in due proportions of sulphur and arsenious acid. As thus obtained, it is in yellow compact opaque masses, of a glassy aspect; yielding a powder of a pale yellow colour.

Artificial orpiment seems to be a substance of uncertain composition, it containing sometimes, according to Guibourt, 94 per cent. of arsenious acid, and only 6 per cent. of the tersulphide of arsenic. On this account it is much more soluble in water than the native orpiment, and consequently a much more powerful poison. It has been administered several times with criminal intentions, and in many of the cases proved fatal. Orpiment is the colouring-matter of the pigment called king's yellow, which is a mixture of arsenious acid with a little tersulphide of arsenic, just as the sample analysed by Guibourt. See KING'S YELLOW.

A proper tersulphide of arsenic may be obtained by passing a stream of sulphuretted hydrogen gas through a solution of arsenious acid in hydrochloric acid. It falls as a brilliant yellow amorphous powder.

Tersulphide of arsenic is insoluble in water and dilute acids, but is decomposed by nitric acid and *aqua regia*. It fuses easily, and when heated in air burns with a pale blue flame, generating arsenious and sulphurous acids. In close vessels it sublimes unchanged. It is dissolved by ammonia, and the caustic fixed alkalis forming colourless solutions, from which it is again precipitated by the addition of an acid. The alkaline sulphides also dissolve it, forming double salts, from which solutions it is precipitated even more completely than from the former, by the addition of an acid.

According to Dr. Paris, Delcroix's depilatory, called *poudre subtile*, consists of quicklime, orpiment, and some vegetable powder.

Orpiment is used by pyrotechnists, and as a pigment: the best kinds of native orpiment being reserved for artists.

ORRIS-ROOT. The dried rhizomes of several species of *Iris*.

ORTHOCLASE. See FELSPAR.

OSIER. *Salix.* The Willow-Tree. About 300 species of these plants have been described. The common white willow is a native of Great Britain and many parts of Europe, and is extensively cultivated. The wood is soft, and is employed in making various small articles. The charcoal prepared from it is considered superior to any other for the manufacture of gunpowder. The bark is very bitter, and from it a bitter principle, *salicine*, is obtained, which has been used with some advantage as a substitute for quinine, and it is sometimes used for adulterating that drug. See SALICINE.

OSMIUM is one of the rare metals, most generally found in the ores of platinum, in which it was discovered by Mr. Tennant in 1803. These ores generally contain the metals palladium, rhodium, osmium, ruthenium, and iridium, mixed with the platinum.

The process for obtaining osmium from these ores has been much simplified by M. Frémy. After the exhaustion of the ores by *aqua regia* there remains a residue, which often contains titaniferous iron and chrome iron; but the most important constituent is an alloy existing in flat plates or scales, of a white colour and metallic lustre, and which was formerly thought to contain only osmium and iridium, but later experiments have proved the presence of ruthenium, and a little rhodium. Frémy takes advantage of the oxidability of osmium and of the volatility of its peroxide. His process consists in roasting the alloy in a current of dry air; for this purpose the residue above mentioned is placed in a porcelain or platinum tube, and heated to redness.

The equivalent of osmium is 99·6; and its symbol, Os.

Five compounds of osmium and oxygen exist, viz.:—*Protoxide*, OsO; it is a dark green powder, slowly soluble in acids. *Sesquioxide*, Os^2O^3, has never been obtained pure; it is formed by heating a solution of osmate of ammonia, when a brown powder falls, which is this compound mixed with some ammonia, which explodes feebly when heated. *Binoxide*, OsO^2, is a black powder, insoluble in acids, and burning to osmic acid when heated in the air. *Osmious acid*, OsO^3; this only exists in combination; it forms a rose-red crystalline powder with potassa ($KO,OsO^3,2HO$); this salt is obtained by adding alcohol to a solution of osmate of potassa; the osmic acid is reduced by the alcohol, and this salt is precipitated; on attempting to separate this acid, it is decomposed into binoxide and osmic acid. *Osmic acid*, OsO^4; the preparation of this compound has already been described; it melts, and even boils, below

212°: its vapour is irritating and deleterious, and has a peculiarly offensive odour, hence the name of the metal from *ὀσμή, an odour.* Three combinations of osmium and chlorine are known: *protochloride,* $OsCl$; *sesquichloride,* Os^2Cl^3 (this only exists in solution); and *bichloride,* $OsCl^2$ (this exists only in a double salt, with chloride of potassium, $OsCl^2 + KCl$). Osmium combines also with phosphorus and sulphur.

OSMIUM-IRIDIUM, or *Iridosmine.* This alloy is found with platinum in the province of Choco, in South America, and in the Ural Mountains. It was first discovered by Mr. Smithson Tennant in the black scales which remain when native platinum is dissolved in *aqua regia.* It is rather abundant with the alluvial gold of California, occurring in small bright lead-coloured scales, sometimes six-sided (*Dana*). It has been recently found in Gippsland, Victoria.

The following analysis of this alloy is by Berzelius:—Iridium 46·77, osmium 49·35, iron 0·74, rhodium 3·15. See IRIDIUM.

OSMOSE FORCE. See EXOSMOSE and ENDOSMOSE.

OSTEOCOLLA. The glue obtained from bones, by removing the earthy phosphates with muriatic acid, and dissolving the cartilaginous residuum in water, at a temperature considerably above the boiling-point.

OTTO, OTTAR, or **ATTAR OF ROSES** (from an Arabic word signifying *aroma*), is a volatile oil, too well-known to require description as to its odour and uses. It is obtained by distilling roses with water. It is manufactured extensively at Ghazipoor in Hindostan, as well as at Shiraz in Persia. Polier says that, to obtain a little less than 3 drachms of otto from 100 lbs. of rose-petals in India, it requires a most favourable season, and the operation to be carefully performed. According to Donald Munro, the otto is procured without distillation, merely by macerating the petals in water; and in India it is sometimes thus prepared: the roses macerating in water are exposed to the sun, when the oil separates and floats on the water. It has also been said to be obtained at Damascus, and other parts of Asia Minor, by the dry distillation of the rose at the temperature of a salt-water bath.

It has little colour. It is combustible; and its vapour forms with oxygen an explosive mixture. Its specific gravity at 90° Fahr. is 0·832. At 57° Fahr., 1,000 parts of alcohol (specific gravity 0·806) dissolve 7 parts; and at 72° Fahr., 33 parts of otto.

Otto of roses consists of two volatile oils: one solid and the other liquid at ordinary temperatures, in the proportion of about one of the former to two of the latter. To separate them, the otto must be frozen, and compressed between folds of blotting-paper, which absorb the liquid, and leave the solid oil. They may also be separated by alcohol (of specific gravity 0·8), which dissolves the liquid and scarcely any of the solid oil. The solid oil, according to Saussure, contains only carbon and hydrogen, and these in equal number of atoms, and is therefore isomeric with oil of turpentine; it occurs in crystalline plates, fusible at 95° Fahr. The liquid oil has not been carefully examined; it is uncertain whether it contains nitrogen, or only carbon, hydrogen, and oxygen.

Turkey supplies the commercial world with otto of roses. The rose-farms are principally situated in the low countries of the Balkan between Selimno and Carloya as far as Philippolis in Bulgaria. It is the Christian inhabitants of this district that are chiefly engaged in the business.

Kizaulik in Roumelia is the head-quarters of the trade. Turkey yields from 50,000 to 75,000 ounces per annum. The average importation of otto of roses into Britain is 12,000 ounces, very nearly the whole of which is from Turkey.

A small quantity of otto of roses is produced in the south of France and in Savoy and the Italian borders.

Pure Turkish otto of roses congeals at + 58° Fahr., and boils at 432° Fahr. Italian otto of roses congeals at + 62° Fahr. A sample otto of roses produced from English-grown roses at Mitcham, remained solid at + 70° Fahr., but above that temperature at once became liquid.

Otto of roses, like other articles that are of value, is systematically adulterated, principally with essence of geranium; when this is the case, the boiling-point is lowered, and the congealing-point raised. The insertion of a sample of otto in a bottle into water cooled with ice is a very good physical test of purity. Spermaceti was at one time used to sophisticate otto, but its insolubility in alcohol rendered it too easily detected.

OUT-CROP. A geological and mining term, to signify that the edge of any inclined stratum, bed of coal, or mineral vein, comes to the surface.

OXALATES are saline compounds of the bases with oxalic acid.

OXALIC ACID (*Acide oxalique*, Fr.; *Sauerkleesäure*, Ger.) is now the object of a considerable chemical manufacture. It is usually prepared, upon the small scale, by the following process:—

One part of sugar is gently heated in a retort with five parts of nitric acid, of specific gravity 1·42, diluted with twice its weight of water; copious red fumes are disengaged, and the oxidation of the sugar proceeds rapidly. When the action slackens, heat may be again applied to the vessel, and the liquid concentrated, by distilling off the excess of nitric acid until it deposits crystals on cooling. These crystals are purified by redissolving in a small quantity of water, and recrystallisation.

Oxalic acid occurs in aggregated prisms when it crystallises rapidly, but in tables of greater or less thickness when slowly formed. They lose their water by crystallisation in the open air, fall into powder, and weigh 0·28 less than before; but still retain 0·14 parts of water, which the acid does not part with, except in favour of another oxide, as when it is combined with oxide of lead. The effloresced acid contains 20 per cent. of water, according to Berzelius.

The effloresced acid may be sublimed in a great measure without decomposition; whereas the ordinary crystallised acid, containing the three equivalents of water, is decomposed by a high temperature into carbonic and formic acids, and carbonic oxide. The crystals of oxalic acid dissolve in eight parts of water at 60° Fahr., and in their own weight, or less, of boiling water; they are also soluble in spirit. The aqueous solution has an intensely sour taste and most powerful acid reaction, and is highly poisonous. In cases of poisoning with this acid the proper antidote is chalk or magnesia, as these substances form with oxalic acid compounds almost insoluble in water, the lime compound being much less soluble than the magnesian. The formula of the crystallised acid is $C^2O^3,HO + 2HO$ ($\mathbf{C^2H^2O^4 + 2H^2O}$); the effloresced acid, C^2O^3,HO ($\mathbf{C^2H^2O^4}$). Oxalic acid is decomposed by hot sulphuric acid into a mixture of carbonic oxide and carbonic acid. The binoxides of lead and manganese effect the same change, becoming reduced to protoxides, which combine with the unaltered acid.

By exposing 100 parts by weight of dry sugar to the action of 825 parts of hot nitric acid of 1·38 specific gravity, evaporating the solution down to one-sixth of its bulk, and setting it aside to crystallise, from 58 to 60 parts of beautiful crystals of oxalic acid may be obtained, according to Schlesinger.

Oxalic acid may be produced by the action of nitric acid upon most vegetable substances, and especially from those which contain no nitrogen, such as well-washed sawdust, starch, gum, and sugar. The latter is the article generally employed, and possesses many advantages over every other material. Treacle, which is a modification of sugar, also comes within the same ranges. A spirit of exaggeration prevails in respect to the amount of produce attainable by oxalic-acid makers from a given weight of sugar. The generality of the statements is absurdly false. One cwt. of good treacle will yield about 116 lbs. of marketable oxalic acid; and the same weight of good brown sugar may be calculated to produce about 140 lbs. of acid. As a general rule, 5 cwts. of saltpetre, or an equivalent of nitrate of soda, with 2½ cwts. of sulphuric acid, will generate sufficient nitric acid to decompose 1 cwt. of good sugar, and yield, as above, 140 lbs. of fair marketable oxalic acid, free from superfluous moisture.

On the large scale leaden vessels, or wood vessels lined with lead, are employed in the manufacture of oxalic acid. For this purpose square open vessels, 8 feet square and 3 feet deep, are a convenient size, the liquor being heated by means of steam passed through a coil of lead pipe. A coil of about 48 feet of one-inch pipe in a vessel of the size above mentioned is sufficient to keep the liquor at the required temperature. In using these vessels, the liquor (whatever it may be) to be converted into oxalic acid is put into them together with the acid employed, and heated until the required decomposition is effected. The liquor is then drawn off by a syphon, or by a cock placed at the bottom of the vessel, into shallow leaden vessels, or wooden vessels lined with lead, to cool and crystallise, and the mother-waters are drawn off from the crystals, and used in the next operation.

A process for the conversion of formic acid into oxalic acid has been patented by Mr. Jullion; and also a process for obtaining oxalic acid from uric acid, this latter being produced from guano, patented by Dr. Wilson Turner. But owing to the cheapness of sugar, these processes are of no commercial value. The patents taken out of late years for the manufacture of oxalic acid have been chiefly confined to the saving of nitric acid, by reconverting the red fumes of nitrous and hyponitric acids into nitric acid.

Instead of cane-sugar or treacle, the saccharine substance obtained by the action of an acid on potato starch is sometimes employed. For this purpose the potatoes are well washed, and then reduced into a fine pulp by rasping, grinding, or other suitable means; such pulp is then washed two or three times, by placing it in water, and well stirring it therein, then permitting the pulp to subside, and running off the water. The pulp thus obtained is next placed in an open vessel of lead, or wood lined with lead, with as much water as will allow of the mixture being boiled freely, by means of steam passed through leaden pipes placed therein. Into the mixture of pulp and water, about 2 per cent. by weight (of the potatoes employed) of sulphuric acid (oxalic acid acts more rapidly) is to be stirred in, which will be at the rate of from 8 to 10 per cent. of acid on the quantity of farina contained in the potatoes; the whole is now to be boiled for some hours, until the pulp of the potatoes is converted into saccharine matter, the completion of this process being readily ascertained by applying a drop of tincture of iodine to a small quantity of boiling liquor placed on the surface of a piece of glass, when, if there be any farina remaining unconverted, a purple colour will be produced. The saccharine product thus obtained is then filtered through a horse-hair cloth, after which it is carefully evaporated in any convenient vessel, until a gallon of it weighs about 14 or 14½ lbs.; it is now in a proper condition to be employed in the manufacture of oxalic acid, by the application of nitric acid, as in the case of operating from sugar or treacle. Horse-chestnuts, deprived of their outer shells, are also applicable to the manufacture of oxalic acid when treated in the way above described for potatoes.

Instead of operating with sulphuric acid, the farina of potatoes and of chestnuts may be treated with diastase, and converted into a liquor similar to that obtained after evaporation from the farina and sulphuric acid before mentioned, using about the same proportion of diastase as before directed for sulphuric acid. In this case the liquor is made of the required strength at once, and the processes of filtration and evaporation are rendered unnecessary.

A new method of preparing oxalic acid, said to be cheaper than any other process, has been introduced by Messrs. Roberts, Dale, and Co. A mixed solution of caustic soda and potash, in the proportion of two equivalents of the former to one of the latter, is evaporated to a sp. gr. of about 1·35. It is then made into a thick paste with sawdust, and heated, with constant stirring, on an iron plate, when the mass intumesces and disengages much inflammable gas. The mixture is then exposed for some hours to a temperature of 400° F., and the grey powder thus obtained is treated with water at about 60° F. The oxalate of soda which remains undissolved is then washed, and decomposed with slaked lime; the oxalate of lime being decomposed in turn by sulphuric acid, and the oxalic acid thus obtained in a free state.

Almost the only commercial article made from oxalic acid is the binoxalate of potash or salt of sorrel. This substance results from the decomposition of carbonate of potash by an excess of oxalic acid. The carbonate of potash is first dissolved in hot water, and the oxalic acid added until the effervescence ceases; after which a similar quantity of oxalic acid to that previously employed is thrown in, and the solution is boiled for a few minutes; and then it is set aside to crystallise. The crystals, after being drained and dried, are fit for the market.

Oxalic acid is employed chiefly for certain styles of discharge in calico-printing (which see), and for whitening the leather of boot-tops. Oxalate of ammonia is an excellent reagent for detecting lime and its salts in any solution. The acid itself, or the binoxalate of potash, is often used for removing ink or iron-mould stains from linen.

OX; OXEN. A sub-tribe of animals belonging to the class *Mammalia*, order *Ruminantia*, family *Bovidæ*, or hollow-horned ruminants. The ox appears from the earliest periods to have been a domesticated animal. Its importance to man is great; not only does its flesh form an article of food, but its skin, its horns, and its hoofs are employed in the arts and manufactures.

OXFORD CHROME. An oxide of iron used in oil and water-colour painting.

OXFORD CLAY. An argillaceous or clayey deposit which is well developed in the neighbourhood of Oxford. It forms the base of the Coral Rag or Coralline Oolite, and extends across England in a north-easterly direction from Weymouth, in Dorsetshire, to the river Humber. Its general character is that of a tough brown or bluish-black clay, sometimes attaining a thickness of five or six hundred feet. It furnishes admirable pasture; a favourable example of which is afforded by the vale of Blackmoor, in Dorsetshire, so famous for its dairy produce.—H. W. B.

OX GALL. A mucous, transparent, ropy liquid, of a greenish brown colour, with a bitter taste, obtained from the gall bladder of the ox. It has many uses in the arts. See Watts's 'Dictionary of Chemistry' (article BILE).

OXIDE OF TIN. See TIN and PUTTY POWDER.

OXIDES are compounds containing oxygen in definite proportions.

They are usually divided into *basic oxides*, which unite with acids; *acid oxides*, which neutralise basic oxides, combining with them; and *neutral oxides*, which do not unite with either bases or acids. In addition to these, are *saline oxides*, or compounds which are produced by the union of two oxides of the same metal.

OXIDES, *for polishing*. The finest *crocus* and jeweller's *rouge* are thus prepared:—Crystals of sulphate of iron are taken from the pans in which they have crystallised, and are put at once into crucibles, or cast-iron pots, and exposed to a high temperature; the greatest care being taken to avoid the presence of dust.

The least-calcined portions are of a scarlet colour, and form the jewellers' rouge for polishing gold or silver articles. The more calcined portions are of a purple or bluish-purple colour, and these form crocus for polishing brass or steel. It is found that the blue particles, which are those which have been exposed to the greatest heat, are the hardest. It will, of course, be understood that the result of the action of heat is to drive off the sulphuric acid from the protoxide of iron, which becomes peroxidised in the process.

Lord Rosse, in the 'Philosophical Transactions,' thus describes his process of preparing his polishing powder:—

'I prepare the peroxide of iron by precipitation with water of ammonia, from a pure dilute solution of sulphate of iron. The precipitate is washed, pressed in a screw-press till nearly dry, and exposed to a heat, which in the dark appears a dull low red. The only points of importance are, that the sulphate of iron should be pure, and the water of ammonia should be decidedly in excess, and that the heat should not exceed that I have described. The colour will be a bright crimson, inclining to yellow. I have tried both potash and soda pure, instead of water of ammonia, but after washing with some degree of care, a trace of the alkali still remained, and the peroxide was of an ochrey colour, and did not polish properly.'

Jewellers' rouge is, however, frequently prepared in London by precipitating sulphate of iron with potash, well working the yellow oxide, and calcining it until it acquires a scarlet colour.

Crocus is sometimes prepared after the manner recommended by Mr. Heath. Chloride of sodium and sulphate of iron are well mixed in a mortar; the mixture is then put into a shallow crucible, and exposed to a red heat. Vapour escapes and the mass fuses. When no more vapour escapes, remove the crucible, and let it cool. The colour of the oxide of iron produced, if the fire has been properly regulated, is a fine violet—if the heat has been too high it becomes black. The mass when cold is to be powdered and washed, to separate the sulphate of soda. The powder of crocus is then to be submitted to a process of careful elutriation, and the finer particles reserved for the more delicate work.

OXIDES OF IRON. Four definite combinations of iron and oxygen are known, namely:—*Protoxide*, FeO; *sesquioxide*, Fe^2O^3; *black or magnetic oxide*, $Fe^3O^4 = FeO, Fe^2O^3$; *Ferric acid*, FeO^3. See IRON.

OXIDES OF LEAD and **TIN.** These are both used for polishing. For oxide of tin, see PUTTY POWDER.

OXIDISED OIL. At a meeting of the Society of Arts, on April 4, 1862, Mr. Frederick Walton read a paper 'On the introduction and use of elastic gums and analogous substances,' which described a new preparation bearing the above name. The following is Mr. Walton's description of the manufacture:—

'Whilst engaged, about two years ago, in a series of experiments on the manufacture of artificial leather, it was of the greatest importance to the success of the material that it should have a coat of fine varnish, which, whilst drying quickly, possessed the flexibility of india-rubber. Copal varnish has always been accounted the best varnish, but made with drying oil combined with gum opal at a high temperature, it will not, of course, be dry, until the action of oxidation has reduced the oil contained therein into a solid film. Whilst revolving in my mind this knotty difficulty, and presenting every phase of it to careful thought, it suddenly occurred to me that if the oil was first dried into a skin, like those I had often seen on paint-cans, but, like other people, had before considered as waste, was dissolved in a volatile solvent, like india-rubber sheet, that the semi-resinous material would immediately, on the evaporation of the solvent, resume, like india-rubber, the form it was in prior to solution. By dipping panes of glass into linseed oil, and allowing the films or layers to dry, then repeating the process, I imitated the manufacture of india-rubber from the milk, and thereby produced a solid elastic substance, composed of many layers of perfectly oxidised oil. Up to this stage I had done nothing new or original, for the oil-sheet manufacturers have for more than a century waterproofed linen by layers of oil. But to treat this semi-resinous matter and render it available to purposes of manufacture, will be admitted to be perfectly new, and I now proceed to describe the invention. Having accumulated a quantity of solid oxidised oil by drying it upon extensive surfaces of any kind, such as prepared cloth, stretched in frames, as described in my patent of January 27, 1860, I then scraped or peeled it off by suitable means.

'At first, as before stated, my attention was solely directed to the attainment of a speedily-drying, flexible varnish at a moderate temperature, but very few experiments with this oxidised oil led me to notice its rubber-like qualities, which I at once conceived might, with further manipulation, and with some combinations, be developed more fully, and become a very valuable substitute for that article.

'Encouraged by success at every step, I proceeded, and soon found that by crushing the solid oxidised oil obtained in sheets as described in my patent, and working it thoroughly in hot mixing rolls, I produced a substance which required only the cohesive nature, which in the early part of this paper we noticed as existing so strongly in india-rubber. The addition of a small proportion of shellac soon gave that which was wanting, and I found in my power a material singularly like caoutchouc when worked into dough, and which could be rolled on to fabrics in the same manner and with the same facility—giving a perfect waterproof cloth, unlike oil-cloth, but having the rubber finish and flexibility. Pigments could easily be added to give colour; the addition of resins gave other, or rather varied proportions of adhesion, useful as affording the means of uniting fabrics as by rubber. Fibre, whether flock or cork, mixed in and rolled into sheets, gave me samples of kamptulicon and other floor-cloths.

'Not only has this singular product been thus assimilated to rubber for uses on fabrics, or combined with fibre for floor-cloths, but it is capable of being worked with pigment and vulcanised exactly as india-rubber has been, and forms a hard compound, like vulcanite and ebonite, excepting that the sulphur is not necessary.'

This preparation has not yet found a place amongst manufactures, and the list of applications given in the last Edition is no longer useful.

OXYGEN (*Oxygène*, Fr.; *Sauerstoff*, Ger.) is a permanent gas, and is best obtained by heating a mixture of chlorate of potash and binoxide of manganese, when the chlorate is decomposed into oxygen and chloride of potassium, $KClO^6 = KCl + O^6$. Oxygen may be obtained from binoxide of manganese alone by the action of heat; but in this case, when used with chlorate of potash, the binoxide seems only to act in moderating the evolution of oxygen from the chlorate. When chlorate of potash alone is used, the evolution of gas does not commence so soon, and often is given off rather suddenly at first, and may cause the fracture of the glass vessel.

Oxygen was first discovered by Dr. Priestley in England, and Scheele in Sweden, in 1774, about the same time, but independently of each other. Dr. Priestley called it *dephlogisticated air*, and Scheele *empyreal air*. It was Lavoisier who gave it the name of *oxygen*, from the idea that it was the acidifying principle in all acids (from ὀξὺς, acid, and γεννάω, I beget, or give rise to); but this name has of late years been shown to be a false one. Oxygen may be obtained from several substances, viz. by heating red oxide of mercury, $HgO = Hg + O$; or by heating three parts of bichromate of potash with four parts of oil of vitriol in a glass retort. The products in the latter case are sulphate of potash, sulphate of chromium, water, and oxygen.

Oxygen is colourless, odourless, tasteless, incombustible, but the most powerful agent in maintaining combustion. According to Regnault, 100 cubic inches of this gas weigh, at 60° Fahr. and barometer at 30 inches, 34·19 grains, and its specific gravity is 1·1056. According to Berzelius and Dulong, its sp. gr. is 1·1026.

Of all known substances oxygen is the most abundant in nature, for it constitutes at least three-fourths of the known terraqueous globe. Water contains eight-ninths of its weight of oxygen; and the solid crust of our globe probably consists of at least one-third part by weight of this principle; for silica, carbonate of lime, and alumina,—the three most abundant constituents of the earth's strata—contain each about one-half their weight of oxygen. Oxygen also constitutes about twenty per cent. by volume, or about twenty-three per cent. by weight, of the atmosphere; and it is an essential constituent of all living beings. Plants, in the sunlight, absorb carbonic acid, decompose it—keeping the carbon and liberating the oxygen; while animals, on the other hand, absorb oxygen and give off carbonic acid. Oxygen is *the* great supporter of combustion; substances which burn in air burn with greatly-increased brilliancy in pure oxygen. Several propositions have been made to produce intense light by the use of pure oxygen gas, in the place of atmospheric air. The Drummond Light, the Bude Light, Fitzmaurice's Light, and others, employ oxygen in combination with hydrogen or carburetted hydrogen at the moment of entering into combustion; and some of these bring in the additional aid of a solid incandescent body, as lime, to increase the intensity of the illuminating power. The useful employment of any of these plans appears to depend upon the production of oxygen by some cheaper process than any at present employed.

Maréchal and Tessié du Mothay prepare oxygen by heating the manganates, permanganates, chromates, and ferrates of the alkalis, in a current of steam. The manganate of soda is used for this purpose in America.

The manganate is crushed to a coarse powder, and is then placed in elliptical retorts, 7 feet long, 1 foot wide, and 2 feet deep. These are placed horizontally, the ellipse being vertical. A current of super-heated steam is then passed through the mass, at first slowly, afterwards more rapidly; when the heat has become sufficiently high, part of the oxygen is eliminated, and passes off with the steam, which latter, being condensed, oxygen remains in a state of tolerable purity. The condensers used are similar to those employed in gas-works to separate the less volatile constituents from the coal-gas. They are simply a system of upright cast-iron U-pipes inverted. The water thus formed is sufficient in quantity to wash all soluble impurities from the gas. Farther impurities are removed in a scrubber, whence the oxygen passes, fit for use, into the gas-holder.

After the manganate of soda has been subject to the action of the steam for about ten minutes, the current is shut off, and atmospheric air blown in its place, the effect of which is to re-oxidise so much of the soda-salt as has parted with its oxygen. The nitrogen of the air escapes. After ten minutes the air is cut off and steam re-introduced, which, as before, carries with it oxygen into the condensers.

Some difficulties have been found in working this process. Theoretically, the manganate should continue to yield oxygen *ad infinitum*; but, in practice, it is found that after being some time in use it loses its porosity, and consequently does not permit the steam to act through its whole mass. It becomes, therefore, necessary to recharge the retorts after not very long intervals. It is believed that, if the steam could be kept perfectly dry throughout the process, a result much more nearly approaching that predicted by theory, would be attained to.

OZOKERITE or **OZOCERITE.** A mineral wax found in the Urpeth Colliery, Newcastle-on-Tyne, at Uphall in Linlithgowshire, and in one or two of the collieries, in South Wales. Its composition is, usually, hydrogen 13·79, carbon 86·20. Ozokerite is found in considerable quantity in Moldavia and in Galicia, and has been used for the distillation of paraffin and the manufacture of candles. See CANDLES; PARAFFIN.

OZONE and **ANTOZONE.** The most convenient method of procuring ozone, or rather an ozonised atmosphere, is to place in a large bottle of air, which can be completely closed, a stick of *phosphorus* freshly scraped. Sufficient distilled water should be poured into the bottle to partially cover the phosphorus; the vessel should then be closed with the stopper, and kept in a room at a temperature between 60° and 70°. The phosphorus is oxidised in the bottle in the usual way; and, during this process of oxidation, a portion of the oxygen passes to the state of ozone, and is diffused through the air in the bottle. The test for its presence is a slip of paper moistened with a solution of starch and iodide of potassium. When ozone is produced, this paper on immersion acquires a blue colour, owing to the oxidation of the potassium, and the production of iodide of starch. If a similar slip of paper is put into a similar bottle of air containing distilled water without phosphorus, no change is produced. In a warm room, the evidence of the presence of ozone in a bottle is usually procured in about ten or twelve minutes; but the maximum quantity of ozone is found in it from two to ten hours. Only a small part of the oxygen (from 1-50th to 1-200th) appears to undergo this change; and if kept long, the ozone may be lost by combining with the oxidising phosphorus. So if the iodide paper be left in the bottle, the blue colour will after a time disappear by the ozone combining with the iodine to form iodic acid. It is not produced in dry oxygen, nor in humid air, or in oxygen mixed with certain gases or vapours which prevent the oxidation of the phosphorus; but it appears to be more readily produced, *cæteris paribus*, when oxygen is mixed with nitrogen, hydrogen, or carbonic acid. By washing and decantation, the ozonised air, which is quite insoluble in water, may be deprived of the phosphorus-vapour associated with it, and kept in well-closed bottles. It is speedily lost by diffusion. Graham found that ozone traversed dry and porous stoneware. Ozone may be produced on a small scale by placing a piece of phosphorus with water in a watch-glass, and inverting over this another glass containing the test-paper or liquid.

Ozone is produced by passing the electric spark silently into pure and *dry* oxygen. Frémy and Becquerel found that pure oxygen contained in a sealed tube, when treated for a sufficient time with a series of electric sparks, underwent a complete conversion into ozone, as the whole contents of the tube, when broken, were absorbed by a solution of alkaline iodide, in which it was immersed. In the electrolytic decomposition of water, the oxygen at the positive pole has ozonic properties, provided the poles employed are of gold or platinum. The hydrogen evolved gave no indication of ozone. Faraday found that a mixture of iodide of potassium and starch was decomposed at the positive pole, even after the gaseous oxygen had been made to pass through a tube containing a layer of cotton soaked in a solution of potash. The object of this arrangement was to arrest any acid which might be simultaneously produced, and thus lead to the decomposition of the iodide. Dr. Letheby found that the ozone thus evolved at the positive pole possessed the same power of colouring strychnia as the oxygen (ozone) liberated by sulphuric acid from the peroxides of manganese and lead, and from chromic acid.

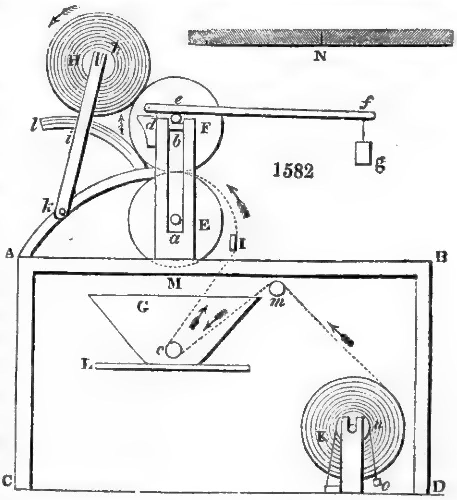
In 1850, Schönbein found that ozone was a product of the slow combustion of *ether.* If a small quantity of ether be poured into a jar or bottle, and a clean glass rod, heated to about 500°, is introduced, acid vapours are given off which redden wetted litmus at the mouth of the jar, and which set free iodine from iodide of potassium, causing the blueing of starch-paper impregnated with this salt. Clean platinum, and even copper or iron, will produce similar effects. The residuary ether in the jar at the same time acquires new properties—those of *antozone.* It bleaches sulphate of indigo, and converts chromic into perchromic acid. *Antozone* is usually produced during this slow combustion of ether, but its existence as a separate principle is exceedingly hypothetical—it is probably a peroxide of hydrogen. See 'Ozone and Antozone,' by Cornelius B. Fox, M.D.; and Watts's 'Dictionary of Chemistry.'

P

PACKFONG. An East Indian alloy, forming a white metal like German silver. It is the Chinese nickel-silver. It appears to contain copper, zinc, and nickel.

PACO, or **PACOS,** is the Peruvian name of an earthy-looking ore, which consists of brown oxide of iron, with almost imperceptible particles of native silver disseminated through it.

PADDING MACHINE (*Machine à plaquer*, Fr.; *Klatsch*, or *Grundermaschine*, Ger.), in calico-printing, is the apparatus for imbuing a piece of cotton cloth uniformly with any mordant. In *fig.* 1582, A B C D represents in section a cast-iron frame, supporting two opposite standards above M, in whose vertical slot the gudgeons *a b* of two copper or bronze cylinders, E F, run; the gudgeons of E turn upon fixed brasses or plummer blocks; but the superior cylinder F rests upon the surface of the under one, and may it with greater or less force by means of the weighted lever *d e f g*, whose centre of motion is at *d*, and which bears down upon the axle of F. K is the roller upon which the pieces of cotton cloth intended to be padded are wound, several of them being stitched endwise together. They receive tension from the action of a weighted belt, *o n*, which passes round a pulley, *n*, upon the end of the roller K. The trough G, which contains the colouring-matter or mordant, rests beneath the cylinder upon the table L, or other convenient support. About two inches above the bottom of the trough there is a copper dip roller, c, under which the cloth passes, after going round the guide roller *m*. Upon escaping from the trough, it is drawn over the half-round stretcher-bar at I, grooved obliquely right and left, as shown at N, whereby it acquires a diverging extension from the middle, and enters with a smooth surface between the two cylinders E F. These are lapped round 6 or 7 times with cotton cloth, to soften and equalise their pressure. The piece of goods glides obliquely upwards, in contact with one-third of the cylinder F, and is finally wound about the uppermost roller H. The gudgeon


1582

of H revolves in the end of the radius $h\,k$, which is jointed at k, and moveable by a mortise at i along the quadrantal arc towards l, as the roller K becomes enlarged by the convolutions of the web. The under cylinder E receives motion by a pulley or rigger upon its opposite end, from a band connected with the driving-shaft of the printshop. To ensure perfect equability in the application of the mordant, the goods are in some works passed twice through the trough; the pressure being increased the second time by sliding the weight g to the end of the lever $d\,f$. See CALICO-PRINTING.

PADDLE. *A metallurgical term.* The name of a tool used by the iron-puddler.

PADDY. The Indian name for rice in the unhusked condition.

PÆONIN, or *Coralline.* See CARBOLIC ACID.

PAGING MACHINE. A self-acting machine for paging books and numbering documents, by Messrs. Waterlow and Sons, is of a very ingenious character. The numbering apparatus consists of five discs, which are provided with raised figures on their periphery, running from 1, 2, 3, &c., to 0; and these figures serve (like letter-press type) to print the numbers required. The discs are mounted at the outer end of a vibrating frame or arm on a common shaft, to which the first or units disc is permanently fixed; and the other four discs (viz. those for marking tens, hundreds, thousands, and tens of thousands) are mounted loosely thereon, so that they need not, of necessity, move when the shaft is rotating: but they are severally caused to move in the following order:—the tens disc performs one-tenth of a revolution for every revolution of the units disc; the hundreds disc makes one-tenth of a revolution for every revolution of the tens disc, and so on. As the discs rise from the paper after every impression, the units disc is caused to perform one-tenth of a revolution (in order that the next number printed may be a unit greater than the preceding one) by a driving click taking into the teeth of a ratchet-wheel, fixed on the left-hand end of the shaft. The movement of the other discs is effected, at intervals, by means of a spring catch, affixed to the side of the units disc, and rotating therewith; which catch, each time that the units disc completes a revolution, is caused by a projection on the inner surface of the vibrating frame to project behind one of the raised figures on the tens disc, and carry it round one-tenth of a revolution on the next movement of the units disc taking place; and then, the catch having passed away from the projection, no further increase in the number imprinted by the tens disc will be effected until the units disc has performed another revolution. Every time that the tens disc completes a revolution, the spring catch causes the hundreds disc to move forward one-tenth of a revolution, and similar movements are imparted to the remaining discs at suitable times. The shaft is prevented from moving, except when it is acted on by the driving click, by a spring detent or pull entering the notches in the periphery of a wheel fixed on the right-hand end of the shaft; and thus the discs are held steady while numbering, and a clear and even impression of the figure is ensured. The leaves of the book to be paged or numbered are laid on the raised part of the table of the machine, covered with vulcanised india-rubber, and as each page is numbered it is turned over by the attendant, so as to present a fresh page on their next descent. As the discs ascend after numbering each page, an inking apparatus (consisting of three rollers mounted in a swing frame, and revolving in contact with each other, so as to distribute the ink which is fed to the first roller evenly on to the third or inking roller) descends and inks the figures which are to be brought into action, when the numbering apparatus next descends. By this means books or documents may be paged or marked with consecutive numbers. For printing duplicate sets of numbers, as for bankers' books, a simple and ingenious contrivance is adopted. This consists in the employment of an additional ratchet-wheel, which is acted on by the driving click that moves the ratchet-wheel above mentioned, and is provided with a like number of teeth to that wheel. But the diameter of the additional ratchet-wheel is increased to admit of the teeth being so formed that the driving click will be thereby held back from contact with every alternate tooth of the first-mentioned ratchet-wheel; and thus the arrangement of the numbering discs will remain unchanged, to give, on their next descent, a duplicate impression of the number previously printed; but, on the re-ascending of the numbering apparatus, the click will act on a tooth of both ratchet-wheels, and move both forward one-tenth of a revolution; and, as the shaft accompanies the first ratchet-wheel in its movements, the number will consequently be changed.

Messrs. Schlesinger and Co. have introduced a paging machine, the capabilities of which are similar to the above, but somewhat differently obtained. The numbering discs in this instance are provided with ten teeth, with a raised figure on the end of each tooth; and they receive the change motion from cog-wheels mounted below them on the same frame. At each descent of the frame a stationary spring catch or hook piece drives round the wheel one tooth, that gears into the teeth of the units disc, and thereby causes the units disc to bring forward a fresh figure. The toothed wheels are somewhat narrower than the numbering discs, but one tooth of each wheel is enlarged laterally to about double the size of the other teeth; so that at the completion of every revolution of the wheel the projecting tooth shall act upon a tooth of the next disc, and carry that disc forward one-tenth of a revolution. By this means the requisite movements of the discs for effecting the regular progression of the numbers are produced; the first wheel driving its own disc, and communicating motion at intervals to the next disc, and the other wheels each receiving motion at intervals from the disc with which it is connected, and transmitting motion, at still greater intervals of time, to the next disc.

The machine is caused to print the figures in duplicate by drawing the spring catch out of action at every alternate descent of the frame, and thereby preventing any change of the figures taking place until after the next impression.

The numbers may be increased two units at each impression, so as to print all even or all odd numbers, by bringing a second catch into action, which causes the unit disc to advance one step during the ascending movement of the frame, in addition to the advance during the descent of the same.

PAINTS are colouring-matters in combination with oil. In most cases for the ordinary paints the basis is white lead, with the colouring agents derived from the mineral or vegetable kingdom mixed with it. This does not apply to artists' colours (see COLOURS). The advantages of lead are, that its carbonate (or white lead) actually combines with the oil, whereas white zinc is merely mechanically suspended in it. In the one case we have a plaster spread over the wood or canvas to which the paint is applied, in the other we have only a fine powder held by the oil so long as it continues permanent, but which washes out when the oily coating begins to give way.

Oxide of zinc, or white zinc, is, however, much used as a paint. Ground with oil, it does not cover the surface of wood so well as a lead paint does, owing to the condition in which it exists, as already explained. It has, however, one advantage over white lead, as it is not liable to tarnish or blacken when exposed to the action of sulphide of hydrogen. It has been stated that white zinc is not injurious, as white lead is, to the health of the painter. This is very questionable. It has been found that the long-continued use of white zinc paint produces a distressing nausea.

A white paint has been made from the oxide of *bismuth*; but the metal is too scarce to make it an article of commercial value. A *tungsten* white was made in tolerably large quantities a few years since, and it was advertised as possessing many advantages; as it has not maintained its ground, we may therefore suppose that the promises were not fulfilled.

Copper is largely used as a paint. The most brilliant greens are compounds of the oxide of this metal with arsenic and other bodies. There are also several blues of great value produced from copper.

Iron.—The oxides of iron, in various forms, are employed in the production of yellow, brown, and black paints. A very beautiful black is produced by calcining with care spathic iron ore, the white carbonate of iron; the result is a black magnetic oxide, which mixes well with oil, and forms a most permanent covering for out-of-door work. Calcined hæmatitic iron ores are also found to produce most permanent colours, which resist the action of the weather in a remarkable manner.

Anthracite, ground to an impalpable powder, has been extensively used, when mixed with a drying oil as a black paint. A considerable quantity of this paint was manufactured at Bideford, in North Devon, where the anthracite is obtained from the well-known culm measures of that district. Nearly all paints employed by the ordinary house-painter should be, however, lead paints to which colour has been imparted by the use of some of the metallic oxides. For artists' paints, see COLOURS; LEAD, OXICHLORIDE; and WHITE LEAD.

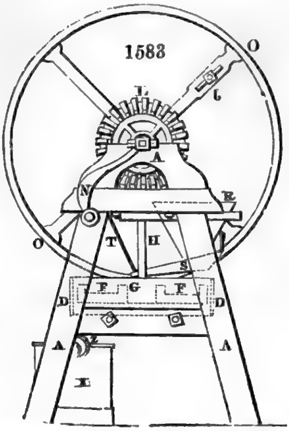
PAINTS, GRINDING OF. There are many pigments, such as common orpiment, or king's yellow, and verdigris, which are strong poisons; others which are very deleterious, and occasion dreadful maladies, such as white lead, red lead, chrome yellow, and vermilion; none of which can be safely ground by hand with the slab and muller, but should always be triturated in a mill. The emanations of white lead cause, first, that dangerous disease the *colica pictonum*, afterwards paralysis, or premature decrepitude and lingering death.

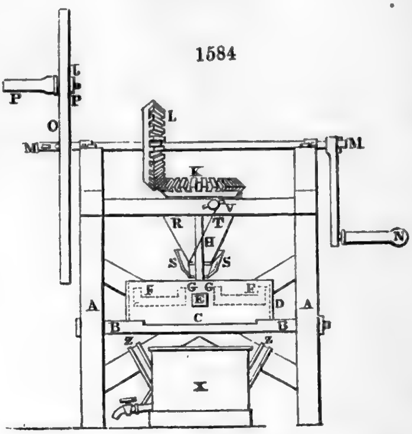
Figs. 1583, 1584, and 1585 exhibit the construction of a good colour-mill in three views: *fig.* 1583 being an elevation shown upon the side of the handle, or where the power is applied to the shaft; *fig.* 1584 a second elevation, taken upon the side of the line *c d* of the plan or bird's-eye view, *fig.* 1585.

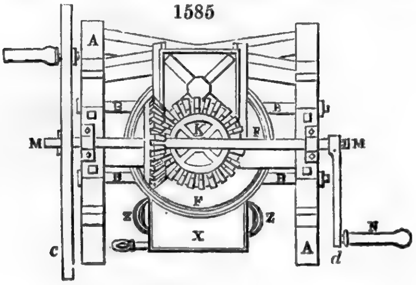
The frame-work A A of the mill is made of wood or cast-iron, strongly mortised or bolted together, and strengthened by the two cross iron bars B B. *Fig.* 1586 is a plan of the millstones. The lying or nether millstone C, *fig.* 1584, is of cast iron, and is channelled on its upper face by corn millstones. It is fixed upon the two iron bars

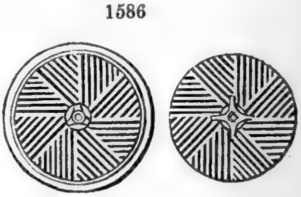
B B, but may be preferably supported upon the three points of adjustable screws, passing up through bearing-bars. The millstone, C, is surrounded by a large iron hoop, D, for preventing the pasty-consistenced colour from running over the edge. It can escape only by the sluice-hole E, *fig.* 1584, formed in the hoop, and is then received in the tub X, placed beneath.

The upper or moving millstone, F, is also made of cast iron. The dotted lines indicate its shape. In the centre it has an aperture with ledges, G, G; there is also a ledge upon its outer circumference, sufficiently high to confine the colour which may occasionally accumulate upon its surface. An upright iron shaft, H, passes into the turning-stone, and gives motion to it. A horizontal iron bevel-wheel, K, *figs.* 1584, 1585, furnished with 27 wooden teeth, is fixed upon the upper end of the upright shaft H. A similar bevel-wheel, L, having the same number of teeth, is placed vertically upon the horizontal iron axis M M, and works into the wheel K. This horizontal axis, M M, bears at one of its ends a handle or winch, N, by which the workman may turn the millstone F; and on the other end of the same axis the fly-wheel, Q, is made fast, which serves to regulate the movements of the machine. Upon one of the spokes of the fly-wheel there is fixed in like manner a handle, P, which may serve upon occasion for turning the mill. This handle may be attached at any convenient distance from the centre by means of the slot and screw-nut J. The colour to be ground is put into the hopper R, below which the bucket, S, is suspended for supplying the colour uniformly through the orifice in the millstone G. A cord or chain, T, by means of which the bucket, S, is suspended at a proper height for pouring out the requisite quantity of colour between the stones, pulls the bucket obliquely, and makes its beak rest against the square upright-shaft H. By this means the bucket is continually agitated in such a way as to discharge more or less colour, according to its degree of inclination. The copper cistern, X, receives the colour successively as it is ground; and when full it may be carried away by the two handles Z Z; or it may be emptied by the stopcock Y, without removing the tub. For many purposes, as for


1583


1584


1585


1586

colour-printing, it is highly important that the paint used should be in the finest possible state. To effect this, at Messrs. De La Rue's and some other large establishments, the colours are passed between finely-polished steel rollers which are, by screws, brought very close together.

PAINTS, VITRIFIABLE. See Porcelain; Pottery; and Stained Glass.

PALISANDER WOOD. A name employed on the Continent for rosewood. Holtzapffel has the following remarks on this wood:—

'There is considerable irregularity in the employment of this name; in the work of Bergeron a kind of striped ebony is figured as *bois de Palixandre*; in other French works this name is considered a synonym of *bois violet*, and stated as a wood brought by the Dutch from their South American colonies, and much esteemed.'

PALLADIUM, a metal possessed of valuable properties, was discovered in 1803, by Dr. Wollaston, in native platinum. It constitutes about 1 per cent of the Columbian ore, and from ¼ to 1 per cent. of the Uralian ore of this metal; occurring nearly pure in loose grains of a steel-grey colour, passing into silver-white, and of a specific gravity of from 11·8 to 12·14; also as an alloy with gold in Brazil; and it is also found in many varieties of native gold. In the nitro-muriatic solution of native platinum, if a solution of cyanide of mercury be poured, the pale yellow cyanide of palladium will be thrown down, which, being ignited, affords the metal. This is the ingenious process of Dr. Wollaston. The palladium present in the Brazilian gold ore may be readily separated as follows:—

Melt the ore along with 2 or 3 parts of silver, granulate the alloy, and digest it with heat in nitric acid of specific gravity 1·3. The solution containing the silver-palladium, for the gold does not dissolve, being treated with chloride of sodium or with hydrochloric acid, will part with all its silver in the shape of a chloride. The supernatant liquor being concentrated and neutralised with ammonia will yield a rose-coloured salt in long silky crystals, the ammonio-chloride of palladium, which, being washed in ice-cold water, and then ignited, will yield 40 per cent. of metal.

Palladium is one of the hardest of the metals; its colour is not so bright as that of silver; it is malleable, ductile, and capable of being welded. This metal is more oxidisable than silver, for it tarnishes in air at the ordinary temperature; when heated in air it becomes blue at first from partial oxidation; but if the temperature be increased, this colour disappears and its brightness returns.

Palladium is sometimes substituted for silver in the manufacture of mathematical instruments. The commoner metals may be plated with palladium by the electrotype process. Palladium is sometimes used in the construction of accurate balances, and for some of the works of chronometers. An alloy of palladium and silver is employed by the dentists from the circumstance that it does not tarnish. The influence of palladium in protecting silver from tarnishing is a remarkable and valuable property. The Wollaston medal, given by the Geological Society in honour of its discoverer, was formerly made of palladium.

PALMITIC ACID. $C^{32}H^{32}O^4$ **($\mathbf{C^{16}H^{32}O^2}$)**. This acid was first discovered in palm-oil, from which it derived its name; it has since been found in many other natural productions, and may also be manufactured artificially from many other substances. It is contained, for instance, in bees'-wax, and that in considerable quantities; the portion of the wax insoluble in boiling alcohol is called *myricine*, and is a palmitate of *myricyle*. This *myricine* requires a *strong* solution of potash to saponify it, and then the palmitic acid is obtained as a palmitate of potash, from which it may be separated by adding an acid.

Several chemical processes have been introduced for obtaining palmitic acid, but none of them have been used commercially for obtaining it, which is largely used in making candles. When thus required, it is obtained in the same manner as stearic acid, by distilling with high-pressure steam. See Candles.

When pure, palmitic acid is a colourless solid substance, without smell, lighter than water. It is quite insoluble in water, but freely soluble in boiling alcohol or ether. These solutions have an acid reaction, and when concentrated become almost solid on cooling; but if more dilute, the palmitic acid separates in groups of fine needles. It fuses at 143·6° Fahr.; and becomes, on cooling, a mass of brilliant pearly scales. It unites with bases to form salts, most of which are insoluble in water. It may also be made to unite with glycerine to form *palmitin*, in which state it previously existed in palm-oil.

PALMITIN. This is the principal constituent of fresh palm-oil. It may be obtained from it by the following process:—

The palm-oil is subjected to pressure to remove the liquid portions; the solid portion is then boiled with alcohol, which dissolves the free fatty acids which may be present. The residue is then crude palmitin; and it is purified by repeated crystallisations with ether. When thus obtained it is in small crystals; these fuse, and become, on cooling, a semi-transparent mass, which may be easily reduced to powder. It is almost entirely insoluble in cold alcohol, and only slightly soluble in boiling alcohol, from which it again separates, on cooling, in flakes. It is soluble in all proportions in boiling ether.

M. Duffy states that there are three modifications of palmitin, differing in their melting-point: the first melting at 115° Fahr., the second melting at 142° Fahr., and the third at 145·2° Fahr.

PALM-OIL. See Oils.

PALM-SUGAR. The juices of many of the palms yield a saccharine matter, from which cane-sugar can be extracted.

PALM-TREE. The woods obtained from the various palms of the tropics pass under different names in commerce, according to the patterns they present. The only two varieties much used are: the Betel-nut palm, or *Areca catechu*, which yields a wood of a light yellow-brown colour; and the Cocoa-nut palm, *Cocos nucifera*. This wood is of a chestnut-brown colour. It is much employed for joists, water-troughs, &c., in small quantities for marquetry, and other ornamental works. We receive this wood under the various names of palm, palmetto, palmyra, nutmeg, leopard, and porcupine woods. The last two receive their names accordingly as the section is made in one direction or another.

If the wood is cut horizontally it exhibits dots, like spice; when cut obliquely, the markings are something like the quills of the porcupine.

PALM-WAX, the produce of the *Ceroxylon Andicola*, a palm growing in tropical America. The stem of the tree is thickly covered with wax, which is scraped off and softened and purified in hot water. It is mixed with tallow to render it less brittle; and in this state it is used in South America for candles. The leaves of the *Carnauba palm* are coated with a layer of wax, which peels off, and is collected when the leaves are dried. Teschemaker informs us that the leaves of the dwarf-palm are imported into the United States from the West Indian Islands for the use of the hatters; they are thickly covered with wax. See Carnauba.

PANIFICATION. The making of bread. See Bread.

PANTILE. A curvilinear tile, so formed to facilitate the flow of water. *Plain tiles* are flat tiles.

PAPAVERINE. $C^{40}H^{21}NO^{8}$ ($\mathbf{C^{20}H^{21}NO^{4}}$). One of the many alkaloïds contained in opium. It was discovered by Merck in 1850, but has been chiefly examined by Dr. Anderson.

PAPER-COAL. (*Papierkohle*, Ger.) A name given to certain layers of lignite, from their leaf-like character; this mineral is known also as *Dysodile*.

PAPER-CUTTING. Some machines have been patented for this purpose; one by Mr. Crompton of Farnworth, and another by Enoch Miller. Mr. Edward Cowper patented a machine which has been extensively employed, and which, therefore, we must describe. It consists of a machine, with a reel on which the web of paper of very considerable length has been previously wound; this web of paper being of sufficient width to produce two, three, or more sheets when cut.

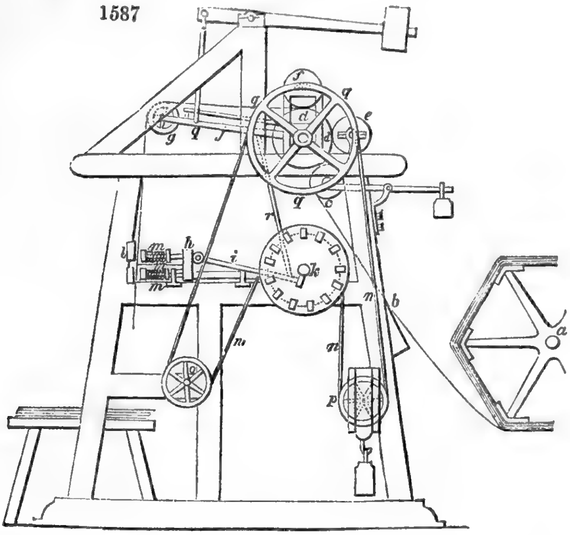
The several operative parts of the machine are mounted upon standards, or framework, of any convenient form or dimensions, and consist of travelling endless tapes to conduct the paper over and under a series of guide-rollers; of circular rotatory cutters for the purpose of separating the web of paper into strips equal to the widths of the intended sheets; and of a saw-edged knife, which is made to slide horizontally, for the purpose of separating the slips into such portions or lengths as shall bring them to the dimensions of a sheet of paper.

The end of the web of paper from the reel *a*, *fig.* 1587, is first conducted up an inclined plane, *b*, by hand; it is then taken hold of by endless tapes extended upon rollers, as in Mr. Cowper's Printing-Machine. These endless tapes carry the web of paper to the roller *c*, which is pressed against the roller *d* by weighted levers, acting upon the plummer-blocks that its axle is mounted in. The second roller, *d*, may be either of wood or metal, having several grooves formed round its periphery for the purpose of receiving the edges of the circular cutters, *e*, mounted upon an axle turning upon bearings in the standards or frame.

In order to allow the web of paper to proceed smoothly between the two rollers, *c*, *d*, a narrow rib of leather is placed round the edges of one or both of these rollers, for the purpose of leaving a free space between them, through which the paper may pass without wrinkling.

From the first roller, *c*, the endless tapes conduct the paper over the second, *d*, and then under a pressing-roller, *f*, in which progress the edges of the circular knives, *e*, revolving in the grooves of the second roller, *d*, cut the web of paper longitudinally into strips of such width as may be required, according to the number of the circular cutters and distances between them.

1587



The strips of paper proceeding onward from between the knife-roller, *d*, and pressing-roller, *f*, conducted by tapes, until they reach a fourth roller, *g*, when they are allowed to descend, and to pass through the apparatus designed to cut them transversely; that is, into sheet-lengths.

The apparatus for cutting the strips into sheets is a sliding knife, placed horizontally upon a frame at *h*, which frame, with the knife *e*, is moved to and fro by a jointed rod, *i*, connected to a crank on the axle of the pulley *k*. A flat board or plate, *l*, is fixed to the standard frame in an upright position, across the entire width of the machine, and this board or plate has a groove or opening cut along it opposite to the edge of the knife. The paper descending from the fourth roller, *g*, passes against the face of this board, and as the carriage with the knife advances, two small blocks, mounted upon rods with springs, *m m*, come against the paper, and hold it tight to the board or plate *l*, while the edge of the knife is protruded forward into the groove of that board or plate, and its sharp saw-shaped teeth passing through the paper, cut one row of sheets from the descending strips; which, on the withdrawing of the blocks, fall down, and are collected on the heap below.

The power for actuating this machine is applied to the reverse end of the axle on which the pulley *k* is fixed, and a band, *n n n n*, passing from this pulley over tension-wheels, *o*, drives the wheel, *q*, fixed to the axle of the knife-roller, *d*; hence this roller receives the rotatory motion, which causes it to conduct forward the web of paper; but the other rollers, *c* and *f*, are impelled slowly by the friction of contact.

The rotation of the crank on the axle of *k*, through the intervention of the crank-rod *i*, moves the carriage *h*, with the knife, to and fro at certain periods, and when the spring blocks *m* come against the grooved plate *l*, they slide their guide rods into them, while the knife advances to sever the sheets of paper. But as sheets of different dimensions are occasionally required, the lengths of the slips delivered between each return of the knife are to be regulated by enlarging or diminishing the diameter of the pulley *k*, which will of course retard or facilitate the rotation of the three conducting rollers, *c*, *d*, *f*, and cause a greater or less length of the paper to descend between each movement of the knife carriage.

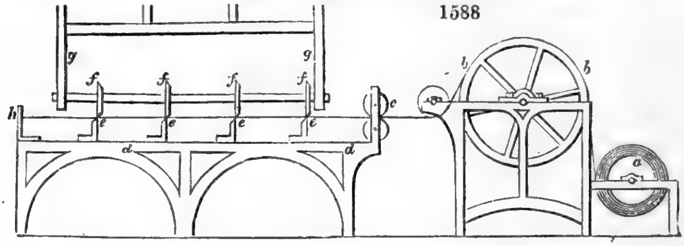
The groove of this pulley *k*, which is susceptible of enlargement, is constructed of wedge-formed blocks, passed through its sides, and meeting each other in opposite directions, so that on drawing out the wedges a short distance, the diameter of the pulley becomes diminished; or by pushing the wedges further in, the diameter is increased; and a tension wheel, *p*, being suspended in a weighted frame, keeps the band always tight.

As it is necessary that the paper should not continue descending while it is held by the blocks, *m m*, to be cut, and yet that it should be led on progressively over the knife roller, *d*, the fourth roller, *g*, which hangs in a lever, *j*, is made to rise at that time, so as to take up the length of paper delivered, and to descend again when the paper is withdrawn. This is effected by a rod, *r*, connected to the crank on the shaft of the aforesaid roller *k*, and also to the under part of the lever, *j*, which lever hanging loosely upon the axle of the knife-roller *d*, as its fulcrum, vibrates with the under-roller, *g*, so as to effect the object in the way described.

The patentee states that several individual parts of this machine are not new, and that some of them are to be found included in the Specifications of other persons, such as the circular cutters *c*, which are employed by Mr. Dickinson (CARD-CUTTING), and the horizontal cutter *h*, by Mr. Hansard; he therefore claims only the general arrangement of the parts in the form of a machine for the purpose of cutting paper, as the subject of his invention.

The machine for cutting paper contrived by Mr. John Dickinson, of Nash Mills, was patented in January 1829. The paper is wound upon a cylindrical roller, *a*, *fig.* 1588, mounted upon an axle, supported in an iron frame or standard. From this roller the paper in its breadth is extended over a conducting drum *b*, also mounted upon an axle turning in the frame or standard, and after passing under a small guide roller, it proceeds through a pair of drawing or feeding rollers, *c*, which carry it into the cutting machine.

1588



Upon a table *d*, *d*, firmly fixed to the floor of the building, there is a series of chisel-edged knives, *e*, *e*, *e*, *e*, placed at such distances apart as the dimensions of the cut sheets of paper are intended to be. These knives are made fast to the table, and against them a series of circular cutters *f*, *f*, *f*, *f*, mounted in a swinging frame *g*, *g*, are intended to act. The length of paper being brought along the table over the edges of the knives up to a stop, *h*, the cutters are then swung forwards, and by passing over the paper against the stationary knives, the length of paper becomes cut into three separate sheets.

The frame *g*, *g*, which carries the circular cutters *f*, *f*, *f*, *f*, hangs upon a very elevated axle, in order that its pendulous swing may move the cutters as nearly in a horizontal line as possible; and it is made to vibrate to and fro by an excentric, or crank, fixed upon a horizontal rotatory shaft extending over the drum *b*, considerably above it, which may be driven by any convenient machinery.

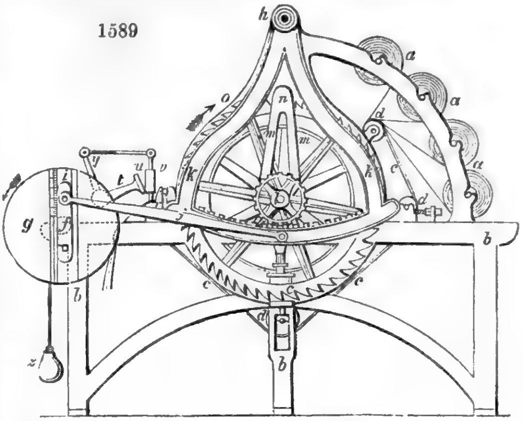
The workmen draw the paper from between the rollers, *c*, and bring it up to the stop *h*, in the intervals between the passing to and fro of the swing-cutters.

The following very ingenious apparatus for cutting the paper web transversely into any desired lengths, was made the subject of a patent by Mr. E. N. Fourdrinier, in June 1831, and has since been performing its duty well in many establishments.

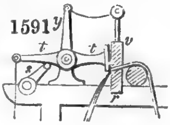
Fig. 1589 is an elevation, taken upon one side of the machine; and *fig.* 1590 is a longitudinal section. *a*, *a*, *a*, *a*, are four reels, each covered with one continuous sheet of paper; which reels are supported upon bearings in the framework *b*, *b*, *b*. *c*, *c*, *c*, is an endless web of felt-cloth passed over the rollers *d*, *d*, *d*, *d*, which is kept in close contact with the under side of the drum *e*, *e*, seen best in *fig.* 1590.

The several parallel layers of paper to be cut, being passed between the drum, *e*, and the endless felt *c*, will be drawn off their respective reels, and fed into the machine, whenever the driving-band is slid from the loose to the fast pulley upon the end of the main shaft *f*. But since the progressive advance of the paper-webs must be arrested during the time of making the cross cut through it, the following apparatus becomes necessary:—A disc, *g*, which carries the pin or stud of a crank, *i*, is made fast to the end of the driving shaft *f*. This pin is set in an adjustable sliding piece, which may be confined by a screw within the bevelled graduated groove, upon the face of the disc *g*, at variable distances from the axis, whereby the excentricity of the stud *i*, and of course the throw of the crank, may be considerably varied. The crank stud, *i*, is connected by its rod *j*, to the swinging curvilinear rack *k*, which takes into the toothed wheel *l*, that turns freely upon the axle of the feed-drum *e*, *e*. From that wheel the arms, *m m*, rise, and bear one or more palls, *n*, which work in the teeth of the great ratchet-wheel *o o*, mounted upon the shaft of the drum *e*.

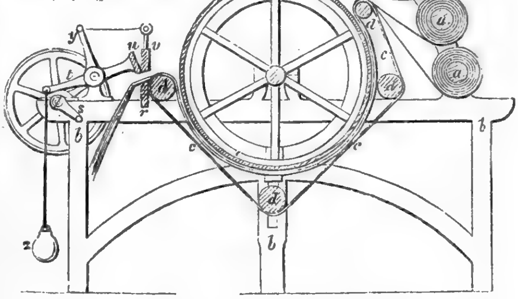
1589



1591



1590



The crank-plate *g* being driven round in the direction of its arrow, will communicate a see-saw movement to the toothed arc *k*, next to the toothed wheel *l*, in gearing with it, and an oscillatory motion to the arms *m m*, as also to their surmounting pall *n*. In its swing to the left hand, the catch of the pall will slide over the slope of the teeth of the ratchet-wheel *o*; but in its return to the right hand, it will lay hold of these teeth, and pull them, with their attached drum, round a part of a revolution. The layers of paper in close contact with the under half of the drum will be thus drawn forward at intervals, from the reels, by the friction between its surface and the endless felt, and in lengths corresponding to the arc of vibration of the pall. The knife for cutting these lengths transversely is brought into action at the time when the swing arc is making its inactive stroke, viz. when it is sliding to the left over the slopes of the ratchet-teeth *o*. The extent of this vibration varies according to the distance of the crank stud *i*, from the centre, *f*, of the plate *g*, because that distance regulates the extent of the oscillations of the curvilinear rack, and that of the rotation of the drum *e*, by which the paper is fed forwards to the knife apparatus. The proper length of its several layers being by the above-described mechanism carried forward over the bed, *r*, of the cutting knife or shears *r*, *v*, whose under blade, *r*, is fixed, the wiper *s*, in its revolution with the shaft *f*, lifts the tail of the lever *t*, consequently depresses the transverse moveable blade *v* (as shown in *fig.* 1591), and slides the slanting blades across each other obliquely, like a pair of scissors, so as to cause a clean cut across the plies of paper. But just before the shears begin to operate, the transverse board, *u*, descends to press the paper with its edge, and hold it fast upon the bed *r*. During the action of the upper blade *v*, against the under *r*, the fall board *u* is suspended by a cord passing across pulleys from the arm *y* of the bell-crank lever *t*, *t*. Whenever the lifter cam, *s*, has passed away from the tail of the bell-crank *t*, the weight *z*, hung upon it, will cause the blade *v* and the pinching board *u*, to be moved up out of the way of the next length of paper, which is regularly brought forward by the rotation of the drum *e*, as above described. The upper blade of the shears is not set parallel to the shaft of the drum, but obliquely to it, and is, moreover, somewhat curved, so as to close its edge progressively upon that of the fixed blade. The blade *v* may also be set between two guide pieces, and have the necessary motion given to it by levers.

PAPER-HANGINGS, called more properly by the French, *papiers peints*. The art of making paper-hangings has been copied from the Chinese, among whom it has been practised from time immemorial. The English first imported and began to imitate the Chinese paper-hangings; but being long exposed to a high Excise duty upon the manufacture, they have only recently carried it to that extent and degree of refinement which the French have been enabled to do, unchecked by taxation. The first method of making this paper was stencilling; by laying upon it, in an extended state, a piece of pasteboard having spaces cut out of various figured devices, and applying different water-colours with the brush. Another piece of pasteboard, with other patterns cut out, was next applied, when the former figures were dry, and new designs were thus imparted. By a series of such operations, a tolerable pattern was executed, but with no little labour and expense. The processes of the calico-printer were next resorted to, in which engraved blocks, of the pear or sycamore, were employed to impress the coloured designs.

Paper-hangings may be distinguished into two classes: 1, those which are really painted, and which are designed in France under the title of *papiers peints*, with brilliant flowers and figures; and 2, those in which the designs are formed by foreign matters applied to the paper, under the name of *papier tontisse*, or flock paper.

The operations common to paper-hangings of both kinds may be stated as follow:—

1. The paper should be well sized.
2. The edges should be evenly cut by an apparatus like the bookbinder's press.
3. The ends of each of the 24 sheets which form a piece should be nicely pasted together; or a web of paper should be taken.
4. Laying the grounds is done with earthy colours of coloured lakes thickened with size, and applied with brushes.

An expert workman, with one or two children, can lay the grounds of 300 pieces in a day. The pieces are now suspended upon poles near the ceiling, in order to be dried. They were then rolled up and carried to the apartment where they are polished, by being laid upon a smooth table, with the painted side undermost, and rubbed with the polisher. Pieces intended to be satined are grounded with fine Paris plaster, instead of Spanish white; and are not smoothed with a brass polisher, but with a hard brush attached to the lower end of a swing polishing rod. After spreading the piece upon the table with the grounded side undermost, the paper-stainer dusts the upper surface with finely-powdered chalk of Briançon, commonly called talc, or with China clay, and rubs it strongly with the brush. In this way the satiny lustre is produced.

The printing operations are as follow:—

Blocks about two inches thick, formed of three separate boards glued together, of which two are made of poplar, and one (that which is engraved) of pear-tree or sycamore, are used for printing paper-hangings, as for calicoes. The grain of the upper layer of wood should be laid across that of the layer below. As many blocks are required as there are colours and shades of colour. To make the figure of a rose, for example, three several reds must be applied in succession, the one deeper than the other, a white for the clear spaces, two and sometimes three greens for the leaves, and two wood colours for the stems; altogether from 9 to 12 for a rose. Each block carries small pin-points fixed at its corners to guide the workman in the insertion of the figure exactly in its place. An expert hand places these guide pins so that their marks are covered and concealed by the impression of the next block; and the finished piece shows merely those belonging to the first and last blocks.

In printing, the workman employs the same *swimming-tub* apparatus which has been described under block-printing (see Calico-Printing), takes off the colour upon his blocks, and impresses them on the paper extended upon a table in the very same way. The tub in which the drum or frame covered with calf-skin is inverted contains simply water thickened with parings of paper from the bookbinder, instead of the pasty mixture employed by the calico-printers. In impressing the colour by the block upon the paper, he employs a lever of the second kind, to increase the power of his arm, making it act upon the block through the intervention of a piece of wood, shaped like the bridge of a violin. The tool is called *tasseau* by the French. A child is constantly occupied in spreading colour with a brush upon the calf-skin head of the drum or sieve, and in sliding off the paper upon a wooden trestle or horse, in proportion as it is finished. When the piece has received one set of coloured impressions, the workman, assisted by his little aid, called a drawer, hooks it upon the drying poles under the ceiling. A sufficient number of pieces should be provided to keep the printer occupied during the whole at least of one day, so that they will be dried and ready to receive another set of coloured impressions by the following morning.

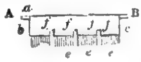
All the colours are applied in the same manner, every shade being formed by means of the blocks, which determine all the beauty and regularity of the design. A pattern drawer of taste may produce a very beautiful effect.

When the piece is completely printed, the workman looks it all over, and if there be any defects, he corrects them by the brush or pencil, applying first the correction of one colour, and afterwards of the rest.

A final satining, after the colours are dried, is communicated by the friction of a finely-polished brass roller, attached by its end gudgeons to the lower extremity of a long swing frame; and acting along the cylindrical surface of a smooth table, upon which the paper is spread.

The *fondu* or rainbow style of paper-hangings is produced by means of an assortment of oblong narrow tin pans, fixed in a frame, close side to side, each being about 1 inch wide, 2 inches deep, and 8 inches long; the colours of the prismatic spectrum, red, orange, yellow, green, &c., are put in a liquid state, successively in these pans; so that when the oblong brush A, B (*fig.* 1592), with guide ledges, *a*, *c*, *b*, is dipped into them across the whole of the parallel row at once, it comes out impressed with the different colours at successive points, *e*, *e*, *e*, *e*, of its length, and is then drawn by the paper-stainer over the face of the woollen drum-head, or sieve of the swimming tub, upon which it leaves a corresponding series of stripes in colours, graduating into one another like those of the prismatic spectrum. By applying his block to the *tear*, the workman takes up the colour in rainbow hues, and transfers these to the paper. *f*, *f*, *f*, *f*, show the separate brushes in tin sheaths, set in one frame.

1592



The operations employed for common paper-hangings are also used for making flock paper, only a stronger size is necessary for the ground. The flocks are obtained from the woollen-cloth manufacturers, being cut off by their shearing machines, called *lewises* by the English workmen, and are preferred in a white state by the French paper-hanging makers, who scour them well, and dye them of the proper colours themselves. When they are thoroughly stove-dried, they are put into a conical fluted mill, like that for making snuff, and are properly ground. The powder thus obtained is afterwards sifted by a bolting machine, like that of a flour-mill, whereby flocks of different degrees of fineness are produced. These are applied to the paper after it has undergone all the usual printing operations. Upon the workman's left hand, and in a line with his printing table, a large chest is placed for receiving the flock powders: it is 7 or 8 feet long, 2 feet wide at the bottom, 3½ feet at top, and from 15 to 18 inches deep. It has a hinged lid. Its bottom is made of tense calf-skin. This chest is called the *drum*; it rests upon four strong feet, so as to stand from 24 to 28 inches above the floor.

The block which serves to apply the adhesive basis of the velvet powders, bears in relief only the pattern corresponding to that basis, which is formed with linseed oil, rendered drying by being boiled with litharge, and afterwards ground up with white lead. The workmen call this the *encaustic*. It is put upon the cloth which covers the inverted swimming tub, in the same way as the common colours are, and is spread with a brush. The workman daubs the blocks upon the *encaustic*, spreads the pigment even with a kind of brush, and then applies it by impression to the paper. Whenever a sufficient surface of the paper has been thus covered, the child draws it along into the great chest, sprinkling the flock powder over it with his hands; and when a length of 7 feet is printed, he covers it up within the drum, and beats upon the calf-skin bottom with a couple of rods to raise a cloud of flock inside, and to make it cover the prepared portion of the paper uniformly. He now lifts the lid of the chest, inverts the paper, and beats it back lightly, in order to detach all the loose particles of the woolly powder.

By the operation just described, the velvet down being applied everywhere of the same colour, would not be agreeable to the eye, if shades could not be introduced to relieve the pattern. For this purpose, when the piece is perfectly dry, the workman stretches it upon his table, and by the guidance of the pins in his blocks, he applies to the flock surface a colour in distemper, of a deep tint, suited to the intended shades, so that he dyes the wool in its place. Light shades are produced by applying some of his lighter water-colours.

Gold-leaf is applied upon the above mordant, when nearly dry; which then forms a proper gold size; and the same method of application is resorted to as for the ordinary gilding of wood. When the size has become perfectly hard, the superfluous gold-leaf is brushed off with a dossil of cotton-wool or fine linen.

The colours used by the paper-hangers are the following:—

1. *Whites.*—These are either white lead, good whitening, or a mixture of he two.

2. *Yellows.*—These are frequently vegetable extracts; as those of weld, or of Avignon or Persian berries, and are made by boiling the substances with water.

Chrome yellow is also frequently used, as well as the *terra di Sienna* and yellow ochre.

3. *Reds* are almost exclusively decoctions of Brazil-wood.

4. *Blues* are either Prussian blue or blue verditer.

5. *Greens* are: Scheele's green, a combination of arsenious acid and oxide of copper; the green of Schweinfurth, or green verditer; as also a mixture of blues and yellows. The use of arsenic in paper-hangings has of late (1859) been the subject of much discussion, and many absurd statements have been made respecting its injurious effects. See ARSENIC.

It has been suggested by Piesse that paper variously coloured in the pulp may have designs printed upon them after the same manner as calicos are printed, sometimes by a discharge-mordant, or by chemical reagents applied by an engraved roller, so as to modify the colour of the pulp.

6. *Violets* are produced by a mixture of a blue and red in various proportions, or they may be obtained directly by mixing a decoction of logwood with alum.

7. *Browns*, *Blacks*, and *Greys*.—Umber furnishes the brown tints. Blacks are either common ivory- or Frankfort black; and greys are formed by mixture of Prussian blue and Spanish white.

All the colours are rendered adhesive and consistent by being worked up with gelatinous size or a weak solution of glue, liquefied in a kettle. Many of the colours are previously thickened, however with starch. Sometimes coloured lakes are employed.

PAPER, INDELIBLE CHEQUE. The facility with which ordinary-written characters can be expunged from paper by chemical bleaching-liquids, acids, and alkalis, has led to the adoption by bankers, for their cheques and drafts, of papers which present obstacles to the fraudulent alteration of the amount and intent of these documents.

Instances of this description of forgery have occasionally occurred. In the spring of 1859 a cheque was paid at a branch of the Bank of England in which both the amount had been altered and the crossing extracted by chemical means.

In 1822 William Robson patented a method of securing bankers' cheques by printing upon their surface vegetable colours equally fugitive with common writing-ink. This method, and its extension to the tinting of writing-papers in the pulp, has been generally adopted by bankers. Those papers which exhibit the perfection of Robson's principle are limited in practice almost exclusively to certain tints obtained from logwood.

Mr. Baildon's paper is a tinted one, from which the colour is removed. The patentee states that he offers *absolute integrity and security* from alteration for any document once issued; and this is obtained by a fluid or ink, which, when used, becomes, in fact, a *permanent dye*, different from any inks yet introduced for this purpose, which are *pigments*. The least attempt to tamper with the ink or paper is instantly detected by a *dark stain* in the paper, which can *never be removed*.

As early as 1817 Gabriel Tigere patented a method of manufacturing 'writing-paper from which it would be extremely difficult, if not impossible, afterwards to extract or discharge any writing from such paper.' This paper was impregnated during the sizing process with the ferrocyanide of potassium.

Mr. William Stone's patent, 1851, was an effort to supply the deficiencies of this method. He added a solution of cyanide of potassium and starch to the ferro- or ferridcyanide of potassium. This method has been fully carried out into practice, but it failed to give the complete security desired. The chemical defects of Tigere's method may be stated thus:—Although admirable in the protection it affords against the application of acids, it is powerless to resist the bleaching-powers of such substances as common chloride of lime (bleaching-powder) in solution; and the ink may also be removed by the application of either of the caustic alkalis. In Stone's method, although by the application of bleaching agents containing chlorine the paper is stained by the blue compound termed the iodide of starch, this is removed again by the application of an alkali.

The Linen Company Bank of Scotland employ green-coloured cheque-paper, on which the sum drawn is written for with a discharge-ink.

In 1837 David Stevenson patented the manufacture of a paper which he specified as containing 'a solution of manganese, mixed with a solution of prussiate of potassa in a liquid form, and mixed with the pulp whereof the writing-paper is to be made.'

In June 1859, Mr. Robert Barclay patented a process of manufacturing a white writing-paper, on which writing-ink is stated to be unalterable for fraudulent purposes by any existing chemical process. He incorporates in the paper an insoluble ferrocyanide and an insoluble salt of manganese, and provides against the discoloration of the paper in the sizing process (which has been a serious objection in practice to the use of the ferrocyanide of potassium) by discarding the use of alum, and sizing the paper by the acetate of alumina in lieu of it. This paper was examined by Professor Brande of the Mint, Professor Miller of King's College, and Mr. R. Warrington of Apothecaries' Hall, who reported favourably on the invention. Writing placed upon this paper strengthens in intensity when exposed to damp, sea, air, or water: influences which ordinarily cause common writing-ink to fade and become illegible.

Dr. Hodges of Belfast, and some others have patented chemically-prepared papers for the use of bankers; but, as far as our enquiries have gone, most bankers appear to think they are already sufficiently secured by the known methods of engraving and printing.

PAPER, MANUFACTURE OF. It is much to be regretted that in tracing the origin of so curious an art as that of the manufacture of modern paper, any definite conclusion as to the precise time or period of its adoption should hitherto have proved altogether unattainable. The Royal Society of Sciences at Göttingen, in 1755 and 1763, offered considerable premiums for that especial object, but unfortunately all researches, however directed, were utterly fruitless. The most ancient manuscript on *cotton paper* appears to have been written in 1050, while Eustathius, who wrote towards the end of the 12th century, states that the Egyptian papyrus had gone into disuse but a little before his time. To reconcile, however, in some measure, contradictory accounts, it may be observed that, on some particular occasions, and by some particular persons, the Egyptian paper might have been employed for several hundred years after it ceased to be in general use; and it is quite certain, that although the new invention must have proved of great advantage to mankind, it could only have been introduced by degrees. Amongst the records which are now preserved in the Record Office, will be found a letter addressed to Henry III., and written previously to 1222, which appears to be upon strong paper, of mixed materials. Several letters of the following reign, which are there preserved, are evidently written on *cotton* paper. Were we able to determine the precise time when paper was first made from cotton, we should also be enabled to fix the invention of the art of paper-making as it is now practised; for the application of cotton to the purposes of paper-making requires almost as much labour and ingenuity as the use of linen rags. Some have conceived, and probably with sufficient reason, that China originally gave birth to the invention. Certain it is, that the art of making paper from vegetable matter reduced to pulp was known and understood there long before it was practised in Europe, and the Chinese have carried it to a high degree of perfection. Several kinds of their paper evince the greatest art and ingenuity, and are applied with much advantage to many purposes. One especially, manufactured from the inner bark of the bamboo, is particularly celebrated for affording the clearest and most delicate impressions from copper-plates, which are ordinarily termed *India proofs.* The Chinese, however, make paper of various kinds, some of the bark of trees, especially the mulberry-tree and the elm, but chiefly of the bamboo and cotton-tree; and occasionally from other substances, such as hemp, wheat-, or rice-straw. To give an idea of the manner of fabricating paper from these different substances, it will suffice (the process being nearly the same in each) to confine our observations to the method adopted in the manufacture of paper from the bamboo—a kind of cane or hollow reed, divided by knots, but larger, more elastic, and more durable than any other reed. The whole substance of the bamboo is at times employed by the Chinese in this operation, but the younger stalks are preferred. The canes, being first cut into pieces of four or five feet in length, are made into parcels, and thrown into a reservoir of mud and water for about a fortnight, to soften them; they are then taken out, and carefully washed, every one of the pieces being again cut into filaments, which are exposed to the rays of the sun to dry, and to bleach. After this they are boiled in large kettles, and then reduced to pulp in mortars, by means of a hammer with a long handle; or as is more commonly the case, by submitting the mass to the action of stampers, raised in the usual way by cogs on a revolving axis. The pulp being thus far prepared, a glutinous substance extracted from the shoots of a certain plant is next mixed with it in stated quantities, and upon this mixture chiefly depends the quality of the paper.

As soon as this has taken place the whole is again beaten together until it becomes a thick viscous liquor, which, after being reduced to an essential state of consistency, by a further admixture of water, is then transferred to a large reservoir or vat, having on each side of it a drying stove, in the form of a ridge of a house, that is, consisting of two sloping sides touching at top. These sides are covered externally with an exceedingly smooth coating of stucco, and a flue passes through the brickwork, so as to keep the whole of each side equally and moderately warm. A vat and a stove are placed alternately in the manufactory, so that there are two sides of two different stoves adjacent to each vat. The workman dips his mould, which is sometimes formed merely of bulrushes, cut in narrow strips, and mounted in a frame, into the vat, and then raises it out again, the water passing off through the perforations in the bottom, and the pulpy paper-stuff remaining on its surface. The frame of the mould is then removed, and the bottom is pressed against the sides of one of the stoves, so as to make the sheet of paper adhere to its surface, and allow the sieve (as it were) to be withdrawn. The moisture, of course, speedily evaporates by the warmth of the stove, but before the paper is quite dry, it is brushed over on its outer surface with a size made of rice, which also soon dries, and the paper is then stripped off in a finished state, having one surface exquisitely smooth, it being seldom the practice of the Chinese to write or print on both sides of the paper. While all this is taking place, the moulder has made a second sheet, and pressed it against the side of the other stove, where it undergoes the operation of sizing and drying, precisely as in the former case.

That very delicate material, which is brought from China in pieces only a few inches square, and commonly, but erroneously, termed *rice paper*, is in reality but the pith of the *Aralia papyrifera*, obtained by cutting the stem spirally round the axis, and afterwards flattening it by pressure. That it is not an artificial production may very readily be perceived by contrasting one of the more translucent specimens with a piece of the finest manufactured paper, by the aid of the microscope.

The precise period at which the manufacture of paper was first introduced into Europe appears to be rather a matter of uncertainty. Paper-mills, moved by water-power, were in operation in Tuscany at the commencement of the fourteenth century; and at Nuremberg, in Germany, one was established in 1390, by Ulman Stromer, who wrote the first work ever published on the art of paper-making. He seems to have employed a great number of persons, all of whom were obliged to take an oath that they would not teach any one the art of paper-making, or make it on their own account. In the following year, when anxious to increase the means of its production, he met with such strong opposition from those he employed, who would not consent to any enlargement of the mill, that it became at length requisite to bring them before the magistrates, by whom they were imprisoned, after which they submitted by renewing their oaths. Two or three centuries later, we find the Dutch, in like manner, so extremely jealous with respect to the manufacture, as to prohibit the exportation of moulds, under no less severe a penalty than that of death.

With reference to any particular *time* or *place* at which this inestimable invention was first adopted in England, all researches into existing records contribute little to our assistance. The first paper-mill erected here is commonly attributed to Sir John Spielman, a German, who established one in 1588, at Dartford, for which the honour of knighthood was afterwards conferred upon him by Queen Elizabeth, who was also pleased to grant him a licence 'for the sole gathering for ten years of all rags, &c., necessary for the making of such paper.' It is, however, quite certain that paper-mills were in existence here long before Spielman's time. Shakspeare, in the Second Part of Henry the Sixth, the plot of which appears laid at least a century previously, refers to a paper-mill. In fact, he introduces it as an additional weight to the charge which Jack Cade is made to bring against Lord Say: 'Thou hast most traitorously corrupted,' says he, 'the youth of the realm in erecting a grammar school: and whereas, before, our forefathers had no other books but the score and the tally, thou hast caused printing to be used, and, contrary to the king, his crown and dignity, thou hast built a paper-mill.'

The earliest trace of the manufacture in this country occurs in a book printed by Caxton, about the year 1490, in which it is said of John Tate—

> Which late hathe in England doo make thys paper thynne,
> That now in our Englyssh thys booke is printed inne.'

His mill was situate at or near Stevenage, in Hertfordshire, and that it was considered worthy of especial notice is evident from an entry made in Henry the Seventh's Household Book, on May 25, 1498—'For a rewarde geven at the papermylne, 16*s.* 8*d.*' And again in 1499—'Geven in rewarde to Tate of the mylne, 6*s.* 8*d.*'

Still, it appears far less probable that Shakspeare alluded to this mill, although established at a period corresponding in many respects with that of occurrences referred to in connection, than to that of Sir John Spielman's, which, standing as it did in the immediate neighbourhood of Jack Cade's rebellion, and being esteemed so important at the time as to call forth the marked patronage of Queen Elizabeth; while the extent of the operations carried on there, if we may judge from the remarks of a poet of the time, were equally calculated to arouse undivided national interest; one can hardly help thinking, that the prominence to which Shakspeare assigns the existence of a paper-mill, coupled, as such allusion is, with an acknowledged liberty, inherent in him, of transposing events, to add force to his style, as also with very considerable doubt as to the exact year in which he wrote the play, that the reference made was to none other than that of Sir John Spielman's establishment of 1588, concerning which we find it said—

'Six hundred men are set to work by him,
That else might starve or seek abroad their bread,
Who now live well, and go full brave and trim,
And who may boast they are with paper fed.'

Be the introduction or establishment of the invention, so far as this country is concerned, when it may, little progress appears to have resulted therefrom, even so late as the middle of the seventeenth century. In 1695, a company was formed in Scotland 'for manufacturing white writing and printing paper,' relating to which, 'Articles concluded and agreed upon at a general meeting at Edinburgh, the 19th day of August,' in the same year, may still be seen by those who are sufficiently curious in the library of the British Museum. It is also recorded in the 'Craftsman' (910), that William the Third granted the Huguenots refuged in England a patent for establishing paper-manufactories, and that Parliament likewise granted to them other privileges, amongst which, in all probability, that very unsatisfactory practice of putting up each ream with two quires composed entirely of sheets spoiled in course of production. Their undertaking, however, like that of many others, appears to have met with very little success.

In fact, the making of paper here scarcely reached any high degree of perfection until about 1760–5, at which period the celebrated James Whatman established his reputation at Maidstone.

The Report of the Juries of the Great Exhibition of 1851 contains an unfortunate error with reference to the position of Mr. Whatman at that time. It is there stated that he gained his knowledge of the manufacture prior to establishing these well-known mills, 'by working as a journeyman in most of the principal paper manufactories of the Continent,' which is altogether an erroneous assertion; for Mr. Whatman, previously to his being engaged as a manufacturer, was an officer in the Kent Militia, and acquired the information, which eventually rendered him so successful, by travelling in the suite of the British Ambassador to Holland, where the best papers were then made, and the insight thus obtained enabled his genius to effect the great improvements afterwards so universally admitted.

At the present time, Whatman's papers are manufactured at two mills, totally distinct, both of which are still worked by the descendants of Mr. Whatman's successors; the paper in the one case being readily distinguished by the water-mark, 'J. Whatman, Turkey Mill,' and in the other, by the water-mark simply 'J. Whatman,' but bearing upon the upper wrapper of each ream the original and well-known stamp, containing the initials L. V. G., which are those of L. V. Gerrevink, as celebrated a Dutch manufacturer prior to Mr. Whatman's improvements as Mr. Whatman's name has since become in all parts of the world.

The comparatively recent application of continuous or rotatory motion has effected wonderful results in the singular conversion of pulp into paper.

The largest paper now made by hand, which is termed Antiquarian, measures 53 inches by 31, and so great is the weight of liquid pulp employed in the formation of a single sheet, that no fewer than nine men are required, besides additional assistance, in raising the mould out of the vat by means of pulleys; while by the aid of the *paper machine*, the most perfect production may be ensured, of a continuous length, and eight feet wide, without any positive necessity for personal superintendence. As an evidence of the enormous length of paper sometimes produced, two rolls were exhibited in 1851, one of which measured 750 yards, and the other 2,400 yards in length.

The principle of paper-making by machinery is simply this: instead of employing moulds and felts of limited dimensions, as was originally the practice, the peculiar merit of the invention consists in the adaptation of an endless wire-gauze to receive the paper-pulp, and again an endless felt, to which in progress the paper is transferred; and thus by a marvellously delicate adjustment, while the wire at one end receives but a constant flow of liquid pulp, in the course of two or three minutes the finished fabric is carefully wound on a roller at the other extremity.

It is a fact, which certainly deserves to be noticed for its singularity as well as for the strong point of view in which it places the merits of this invention, that an art of such great importance to society as that of the manufacture of paper, should have remained for at least eight centuries since paper is first believed to have been in use, and that upwards of 200 of those years should have elapsed since its first introduction into England, without any mechanical improvement whatever as regards the processes which were then employed. It is true, that various attempts from time to time were made, but in every instance they appear to have met with very little success. In France, an ingenious artist (Monsieur Montgolfier) contrived three figures in wood to do the work of the vatman, the coucher, and the layer; but, after persevering for six months, and incurring considerable expense, he was at length compelled to abandon his scheme. And although paper was previously manufactured in China, in Persia, and indeed throughout all Asia, sometimes of considerable length, it was so, not by machinery, but by means of a mould of the size of the paper intended to be made, suspended like a swing, and having men placed at the distance of about every four feet, for the purpose of producing an uniform shaking motion, after the mould had been immersed in the vat, in order to compact the pulp.

Such, then, was the rude state of this important manufacture, even up to the commencement of the present century, when a small working model of a continuous machine was introduced into this country from France by Mr. John Gamble, a brother-in-law to Monsieur Leger Didot, the proprietor at that time of the paper manufactory at Essonne.

The individual to whose genius we owe that beautiful contrivance, which has since been adopted wherever the want which it was designed to remedy has been truly felt, and which has contributed in an eminent degree to the advancement of civilisation, was an unassuming clerk in the establishment of Monsieur Didot, named Louis Robert, who following his favourite pursuit of inventing and improving, not unfrequently had to bear the reproach of wasting time on an invention that could never be brought to perfection. Fortunately, however, the patience and attention of this persevering man were at length sufficiently rewarded by the completion of a small model not larger than a bird organ, which enabled him to produce paper of a continuous length although but the width of a piece of tape. So successful was this performance that his employer, instead of continuing to thwart his progress, was now induced to afford him the means of making a model upon a larger scale, and in a few months a machine was completed capable of making paper the width of Colombier (24 inches), for which the consumption in France was very great. After a series of experiments and improvements, Louis Robert applied to the French Government for a patent or *brevet d'invention*, which he obtained in 1799 for a term of fifteen years, and was awarded the sum of 8,000 francs as a reward for his ingenuity. The Specification of this patent is published in the second volume of the 'Brevets d'Inventions Expirés.' Shortly afterwards, M. Didot purchased Louis Robert's patent and paper-machine for 25,000 francs, to be paid by instalments; but not fulfilling his engagements, the latter commenced legal proceedings, and recovered possession of his patent, by a decision dated June 23rd, 1801. Towards the close of the year 1800 M. Didot proposed to his brother-in-law, Mr. Gamble, that patents should be taken out in England, and suggested that he being an Englishman, and holding a situation under the British Government, would in all probability accomplish it without much difficulty. To this proposition Mr. Gamble assented, and in the month of March 1801, he left Paris for London, where, happily for the vigorous development of this project, he obtained an introduction immediately upon his arrival to one of the principal wholesale stationery houses in Great Britain—a firm of considerable opulence—and to those gentlemen he mentioned the nature and circumstances of his visit, at the same time showing them several rolls of the paper of great length, which had been made at Essonne by Louis Robert's machine, and which induced them to take a share in the patent.

The firm alluded to was that ot the Messrs. Fourdrinier—a name which has indeed become alike famous and unfortunate—and this transaction it was which first connected them with the paper-machine. In the year 1801, Mr. Gamble returned to Paris, and concerted measures with Monsieur Leger Didot and Louis Robert, to have the working model, which was then at Essonne, sent over to England to assist in the construction of other machines; and the following year M. Didot arriving in London, was introduced by Mr. Gamble to the Messrs. Fourdrinier, when a series of experiments for improving the machine was considered desirable and at once commenced. But in order to accomplish the arduous object which those gentlemen then had in view, they laboured without intermission for nearly six years, when, after incurring an expense of 60,000*l.*, which was borne exclusively by the Messrs. Fourdrinier, they at length succeeded in giving some further organisation and connection to the mechanical parts, for which they likewise obtained a patent, and finding eventually that there was little prospect of being recompensed for labour and risk, or even reimbursed their expenses, unless Parliament should think proper to grant an extension of the patent, they determined upon making a fresh application to the Legislature for that purpose. But, it would appear that although in the Bill as it passed the House of Commons, such prolonged period extended to fourteen years, in the Lords it was limited to seven, with an understanding that such term should be extended to seven years more in the event of the patentees proving, upon a future application, that they had not been sufficiently remunerated. No such application, however, was made, in consequence of a Standing Order of the House of Lords, placed on their Journals subsequently to the passing of the said act; which regulation had the effect of depriving the Messrs. Fourdrinier of any benefit whatever from the invention; and ultimately, so great were the difficulties they had to encounter, and so little encouragement or support did they receive, that the time and attention required to mature this valuable invention, and the large capital which it absorbed, were the means of reducing those wealthy and liberal men to the humiliating condition of bankruptcy.

In reverting strictly to the manufacture of paper, the nature of some of the materials employed first claim attention. Silks, woollens, flax, hemp, and cotton, in all their varied forms, whether as cambric, lace, linen, holland, fustian, corduroy, bagging, canvas, or even as cables, are or can be used in the manufacture of paper of one kind or another. Still, rags, as of necessity they accumulate and are gathered up by those who make it their business to collect them, are very far from answering the purposes of paper-making. Rags, to the paper-maker are almost as various in point of quality or distinction, as the materials which are sought after through the influence of fashion. Thus the paper-maker, in buying rags, requires to know exactly of what the bulk is composed. If he is a manufacturer of white papers, no matter whether intended for writing or printing, silk or woollen rags would be found altogether useless, inasmuch as it is well known, the bleach will fail to act upon any animal substance whatever. And although he may purchase even a mixture in proper proportions adapted for the quality he is in the habit of supplying, it is as essential in the processes of preparation that they shall previously be separated. Cotton in its raw state, as may be readily conceived, requires far less preparation than a strong hempen fabric, and thus, to meet the requirements of the paper-maker, rags are classed under different denominations, as for instance, besides *fines* and *seconds*, there are *thirds*, which are composed of fustians, corduroy, and similar fabrics; *stamps* or *prints* (as they are termed by the paper-maker), which are coloured rags, and also innumerable foreign rags, distinguished by certain well-known marks, indicating their various peculiarities. It might be mentioned, however, that although by far the greater portion of the materials employed are such as have already been alluded to, it is not from their possessing any exclusive suitableness—since various fibrous vegetable substances have frequently been used, and are indeed still successfully employed—but rather on account of their comparatively trifling value, arising from the limited use to which they are otherwise applicable.

To convey some idea of the number of substances which have been really tried; in the library of the British Museum may be seen a book printed in Low Dutch, containing upwards of sixty specimens of paper, made of different materials, the result of one man's experiments *alone*, so far back as the year 1772. In fact, almost every species of tough fibrous vegetable, and even animal substance, has at one time or another been employed: even the roots of trees, their bark, the bine of hops, the tendrils of the vine, the stalks of the nettle, the common thistle, the stem of the hollyhock, the sugar-cane, cabbage-stalks, beet-root, wood-shavings, sawdust, hay, straw, willow, and the like. Straw is frequently used in connection with other materials, such as linen or cotton rags, and even with considerable advantage, providing the processes of preparation are thoroughly understood. Where such is not the case, and the silica contained in the straw has not been destroyed (by means of a strong alkali), the paper will invariably be found more or less brittle; in some cases so much so as to be hardly applicable to any purpose whatever of practical utility. The waste, however, which the straw undergoes, in addition to a most expensive process of preparation, necessarily precludes its adoption to any great extent. Two inventions have been patented for manufacturing paper entirely from wood. One process consists in first boiling the wood in caustic soda-lye in order to remove the resinous matter, and then washing to remove the alkali; the wood is next treated with chlorine gas or an oxygenous compound of chlorine in a suitable apparatus, and washed to free it from the hydrochloric acid formed: it is now treated with a small quantity of caustic soda, which converts it instantly into pulp, which has only to be washed and bleached, when it will merely require to be beaten for an hour or an hour and a half in the ordinary beating-engine, and made into paper. The other invention is very simple, consisting merely of a wooden box enclosing a grindstone, which has a roughened surface, and against which the blocks of wood are kept in close contact by a lever, a small stream of water being allowed to flow upon the stone as it turns, in order to free it of the pulp, and to assist in carrying it off through an outlet at the bottom. Of course the pulp thus produced cannot be employed for any but the coarser kinds of paper. For all writing and printing purposes, which manifestly are the most important, nothing has been discovered to greatly lessen the value of rags, neither is it at all probable that there will, inasmuch as rags, of necessity, must continue accumulating; and before it will answer the purpose of the paper-maker to employ new material, which is not so well adapted for his purpose as the old, he must be enabled to purchase it for considerably less than it would be worth in the manufacture of textile fabrics; and, besides all this, rags possess in themselves the very great advantage of having been repeatedly prepared for paper-making by the numerous alkaline washings which they necessarily receive during their period of use.

With all the drawbacks attending the preparation of straw, it is an exceedingly useful material for the manufacture of certain kinds of paper. A thick brown paper, of tolerable strength, may be made from it cheaply; but for printing or writing purposes only an inferior description can be produced, and of little comparative strength to that of rag-paper. Its chief and best use is that of imparting stiffness to common newspaper. Some manufacturers prefer for this purpose an intermixture of straw with paper shavings, and others, in place of the paper shavings, give the preference to rags. The proportion of straw used in connection with rags or paper-shavings varies from 50 to 80 per cent.

The cost of producing two papers of equal quality, one entirely from straw and the other entirely from rags, would be very nearly equal; the preparation, which includes power, labour, and chemicals, being very much greater in the case of the straw; indeed from two to three times as much as that of rags.

In order to reduce the straw to a suitable consistency for paper-making, it is placed in a boiler with a large quantity of strong alkali, and with a pressure of steam equal to 120 lbs., and sometimes to 150 lbs., per square inch; the extreme heat being attained in super-heating the steam after it leaves the boiler, by passing it through a coiled pipe over a fire, and thus the silica becomes destroyed, and the straw softened to pulp, which, after being freed from the alkali by washing it in cold water, is subsequently bleached and beaten in the ordinary rag-engine, to which we shall presently refer.

The annual consumption of rags in this country alone far exceeds 120,000 tons, three-fourths of which are imported, Italy and Germany furnishing the principal supplies.

All that can be said as to the suitableness of fibre in general may be summed up in very few words: any vegetable fibre having a corrugated edge, which will enable it to cohere in the mass, is fit for the purpose of paper-making. Among the many fibres that have been introduced for use in this manufacture, the most important undoubtedly is the coarse grass known as *Esparto* in Spain, and as *Alfa* in Northern Africa. It was first imported by Mr. Noble in 1851, but it was not until the scarcity of cotton was felt during the American War that paper-makers fully realised the value of esparto fibre; in 1868 as much as 96,000 tons were imported. Other fibres have recently been used, such as those of the diss-grass, the dwarf-palm, the baobab-tree, and the New Zealand flax; but it is said that none of these can successfully compete with esparto. Canada rice has recently been recommended as an excellent paper-making material.

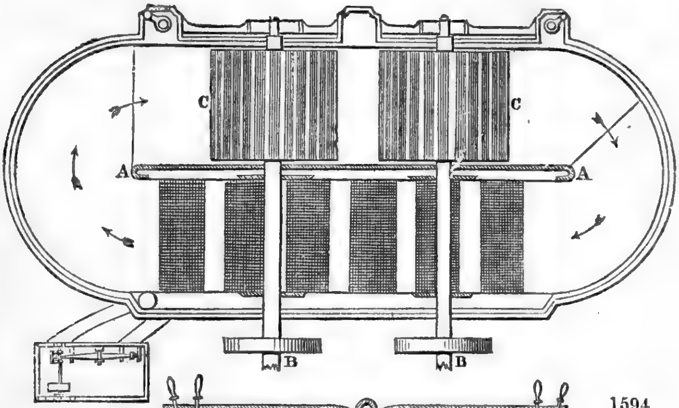
In considering the various processes or stages of the manufacture of paper, we have first to notice that of carefully sorting and cutting the rags into small pieces, which is done by women; each woman standing at a table-frame, the upper surface of which consists of very coarse wire-cloth; a large knife being fixed in the centre of the table, nearly in a vertical position. The woman stands so as to have the back of the blade opposite to her, while at her right hand, on the floor, is a large wooden box, with several divisions. Her business consists in examining the rags, opening the seams, removing dirt, pins, needles, and buttons of endless variety, which would be liable to injure the machinery, or damage the quality of the paper. She then cuts the rags into small pieces, not exceeding 4 inches square, by drawing them sharply across the edge of the knife; at the same time keeping each quality distinct in the several divisions of the box placed on her right hand. During this process, much of the dirt, sand, and so forth, passes through the wire-cloth into a drawer underneath, which is occasionally cleaned out. After this, the rags are removed to what is called the *dusting-machine*, which is a large cylindrical frame covered with similar coarse iron wire-cloth, and having a powerful revolving shaft extending through the interior, with a number of spokes fixed transversely, nearly long enough to touch the cage. By means of this contrivance, the machine being fixed upon an incline of some inches to the foot, the rags, which are put in at the top, have any remaining particles of dust that may still adhere to them effectually beaten out by the time they reach the bottom.

The rags being thus far cleansed, have next to be boiled in an alkaline lye or solution, made more or less strong as the rags are more or less coloured, the object being to get rid of the remaining dirt and some of the colouring-matter. The proportion is from 4 to 10 lbs. of carbonate of soda with one-third of quicklime to the cwt. of material. In this the rags are boiled for several hours, according to their quality.

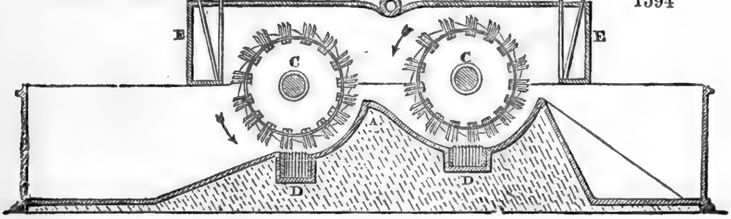
The method generally adopted is that of placing the rags in large cylinders, which are constantly, though slowly, revolving, thus causing the rags to be as frequently turned over, and into which a jet of steam is cast with a pressure of something near 30 lbs. to the square inch.

After this process of cleansing, the rags are considered in a fit state to be torn or macerated until they become reduced to a pulp, which was accomplished, some fifty years since, by setting them to heat and ferment for many days in close vessels, whereby in reality they underwent a species of putrefaction. Another method subsequently employed was that of beating them by means of stamping-rods, shod with iron, working in strong oak or stone mortars, and moved by water-wheel machinery. So rude and ineffective, however, was this apparatus, that no fewer than 40 pairs of stamps were required to operate a night and a day in preparing 1 cwt. of material. At the present time the average weekly consumption of rags, at many paper-mills, exceeds even 30 tons. The cylinder- or engine-mode of comminuting rags into paper-pulp appears to have been invented in Holland, about the middle of the last century, but received very little attention here for some years afterwards. The accompanying figures (*figs.* 1593 and 1594) will serve to convey some idea of the wonderful rapidity with which the work is at present accomplished. No less than *twelve tons* per week can now be prepared by means of this simple contrivance. The horizontal section (*fig.* 1594) represents an oblong cistern, of cast iron, or wood lined with lead, into which the rags, with a sufficient quantity of water, are received. It is divided by a partition, as shown (A), to regulate the

1593



1594



course of the stuff; the spindle upon which each cylinder, C, moves, extending across the engine, and being put in motion by a band-wheel or pinion at the point, B. One cylinder is made to traverse at a much swifter rate than the other, in order that the rags may be the more effectually triturated. The cylinders, C, as shown in the vertical section, are furnished with numerous cutters, running parallel to the axis, and again beneath them similar cutters are mounted (D) somewhat obliquely, against which, when in motion, the rags are drawn by the rapid rotation of the cylinders, and thus reduced to the smallest filaments requisite, sometimes not exceeding the sixteenth of an inch in length; the distance between the fixed and moveable blades being capable of any adjustment, simply by elevating or depressing the bearings upon which the necks of the shaft are supported. When in operation, it is of course necessary to enclose the cylinders in a case, as shown, E E, otherwise a large proportion of the rags would, inevitably, be thrown out of the engine. The rags are first worked coarsely, with a stream of water running through the engine, which tends effectually to wash them, as also to open their fibres; and in order to carry off the dirty water, what is termed a *washing drum* is frequently employed, consisting simply of a framework covered with very fine wire-gauze, in the interior of which, connected with the shaft or spindle, which is hollow, are two suction tubes, and by this means, on the principle of a syphon, the dirty water constantly flows away through a larger tube running down outside, which is connected with that in the centre, without carrying away any of the fibre.

After this, the mass is placed in another engine, where, if necessary, it is bleached by an admixture of chloride of lime, which is retained in the engine until its action becomes apparent. The pulp is then let down into large slate cisterns to steep, prior to being reduced to a suitable consistency by the beating-engine, as already described. The rolls or cylinders, however, of the beating-engine are always made to rotate much faster than when employed in washing or bleaching, revolving probably from 120 to 150 times per minute, and thus, supposing the cylinders to contain 48 teeth each, passing over eight others, as shown in the figures, effecting no fewer than 103,680 cuts in that short period. From this the great advantage of the modern engine over the old-fashioned mortar machine, in turning out a quantity of paper-pulp, will be at once apparent. The introduction of colouring-matter in connection with the paper-manufacture is accomplished simply by its intermixture with the pulp while in process of beating in the engine.

Although the practice of blueing paper is not, perhaps, so customary now as was the case a few years back, the extent to which it is still carried may be a matter of considerable astonishment. On its first introduction, when, as regards colour, the best paper was anything but pleasing, so striking a novelty would no doubt be hailed as a great improvement, and as such received into general use, but the superior delicacy of a *first-class* paper now made without any colouring-matter whatever, and without any superfluous marks on its surface, is so truly beautiful, both in texture and appearance, as to occasion some surprise that it is not more generally used.[1]

Common materials are frequently and very readily employed, through the assistance of colouring-matter, which tends to conceal imperfections. Indeed, it would be difficult to name an instance of apparent deception more forcible than that which is accomplished by the use of ultramarine. Until recently the fine blueish tinge given to many writing-papers was derived from the admixture of that formerly expensive, but now, being prepared artificially, cheap, mineral blue; 1 pound of ultramarine going farther than 4 of smalts, the former necessarily meets with more extended application, and where its use is rightly understood, and the materials employed instead of being fine rags, comparative rubbish, excessively bleached, its application proves profitable to the paper-maker in concealing for a time all irregularities, and making the paper surpass in appearance the best kinds. The oxide of cobalt, generally termed *smalts*, has still the advantage over the ultramarine of imparting a colour which will endure for a much longer period.

At first the introduction of ultramarine led to some difficulty in sizing the paper, for so long as smalts continued to be used, any amount of alum might be employed, and it was actually added to the size to preserve it from putrefaction. But since artificial ultramarine is bleached by alum, it became of course necessary to add this salt to the size in very small proportions, and, as a natural consequence, the gelatine was no longer protected from the action of the air, which led to incipient decomposition, and in such cases the putrefaction once commenced, proceeded even after the size was dried on the paper, and gave to it a most offensive smell, which rendered the paper unsaleable. This difficulty, however, has now been overcome, and providing the size be quite free from taint when applied to the paper, and quickly dried, putrefaction will not subsequently occur; but if decay has once commenced, it cannot arrested by drying only.

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[1] See Richard Herring's 'Pure Wove Writing Paper.'

The operation of paper-making, after the rags or materials to be used have been thus reduced and prepared, may be divided into two kinds: that which is carried on in hand-mills, where the formation of the sheet is performed by manual labour; and that which is carried on in machine-mills, where the paper is produced upon the machine wire-cloth in one continuous web.

With respect to hand-made papers, the sheet is formed by the vatman's dipping a mould of fine wire-cloth fixed upon a wooden frame, and having what is termed a deckle, to determine the size of the sheet, into a quantity of pulp which has been previously mixed with water to a requisite consistency; when, after gently shaking it to and fro in a horizontal position, the fibres become so connected as to form one uniform fabric, while the water drains away. The deckle is then removed from the mould, and the sheet of paper turned off upon a felt, in a pile with many others, a felt intervening between each sheet, and the whole subjected to great pressure, in order to displace the superfluous water; when, after being dried and pressed without the felts, the sheets are dipped into a tub of fine animal size, the superfluity of which is again forced out by another pressing; each sheet after being finally dried, undergoing careful examination before it is finished.

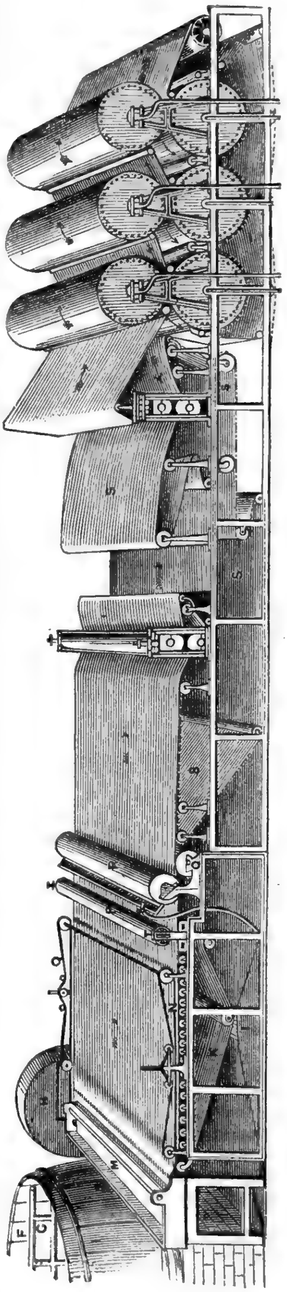
Thus we have, first, what is termed the *water-leaf*, the condition in which the paper appears after being pressed between the felts—this is the first stage. Next, a sheet from the bulk, as pressed without the felts, which still remains in a state unfit for writing on, not having been sized. Then a sheet after sizing, which completely changes its character; and lastly, one with the finished surface. This is produced by placing the sheets separately between very smooth copper-plates, and then passing them through rollers, which impart a pressure of from 20 to 30 tons. After only three or four such pressures, it is simply called 'rolled,' but if passed through more frequently, the paper acquires a higher surface, and is then called 'glazed.'

The paper-making machine is constructed to imitate in a great measure, and in some respects to improve, the processes used in making paper by hand; but its chief advantages are the increased rapidity with which it accomplishes the manufacture, and the means of producing paper of any size which can practically be required.

By the agency of this admirable contrivance, which is so adjusted as to produce the intended effect with unerring precision, a process which, in the old system of paper-making, occupied about three *weeks* is now performed in as many *minutes*.

The paper-making machine (*fig.* 1594) is supplied from the 'chests' or reservoir, F, into which the pulp descends from the beating-engine, when sufficiently ground; being kept in constant motion, as it descends, by means of the agitator, G, in order that it shall not settle. From this reservoir the pulp is again conveyed by a pipe into what is technically termed the 'lifter,' H, which consists of a cast-iron wheel, enclosed in a wooden case, and having a number of buckets affixed to its circumference. The trough, I, placed immediately beneath the endless wire, K, is for the purpose of receiving the

1594



water which drains away from the pulp during the process of manufacture, and as this water is frequently impregnated with certain chemicals used in connection with paper-making, it is returned again by a conducting spout, into the 'lifter,' where, by the rotation of the buckets, both the pulp and back-water become again thoroughly mixed, and are together raised by the lifter through the spout, L, into the trough, M, where the pulp is strained by means of a sieve or 'knotter,' as it is called, which is usually formed of brass, having fine slits cut in it to allow the comminuted pulp to pass through, while it retains all lumps and knots; and so fine are these openings, in order to free the pulp entirely from anything which would be liable to damage the quality of the paper, that it becomes necessary to apply a means of exhaustion underneath, in order to facilitate the passage of the pulp through the strainer.

The lumps collected upon the top of this knotter, more particularly when printing-papers are being manufactured, are composed to a considerable extent of india-rubber, which is a source of much greater annoyance to the paper-maker than is readily conceived. For, in the first place, it is next to impossible in sorting and cutting the rags to free them entirely from the braiding, and so forth, with which ladies adorn their dresses; and, in the next, the bleach failing to act upon a substance of that character, the quality of the paper becomes greatly deteriorated by the large black specks which it occasions, and which, by the combined heat and pressure of the rolls and cylinders, enlarge considerably as it proceeds.

Passing from the strainer, the pulp is next made to distribute itself equally throughout the entire width of the machine, and is afterwards allowed to flow over a small lip or ledge, in a regular and even stream, whence it is received by the upper surface of the endless wire, K, upon which the first process of manufacture takes place. Of course the thickness of the paper depends in some measure upon the speed at which the machine is made to travel, but it is mainly determined by the quantity of pulp allowed to flow upon the wire, which, by various contrivances, can be regulated to great nicety. Paper may be made by this machine considerably less than the thousandth of an inch in thickness, and, although so thin, it is capable of being coloured, it is capable of being glazed, it is capable of receiving a water-mark; and, what is perhaps still more astonishing, a strip not exceeding 4 inches in width is sometimes capable of sustaining a weight of 20 lbs., so great is its tenacity.

But to return to the machine itself. The quantity of pulp required to flow from the vat, M, being determined, it is first received by the continuous woven wire, K, upon which it forms itself into paper; this wire-gauze, which resembles a jack-towel, passing over the small copper rollers, N, round the larger one, marked O, and being kept in proper tension by two others placed underneath. A gentle vibratory motion from side to side is given to the wire, which assists to spread the pulp evenly, and also to facilitate the separation of the water; and by this means, aided by a suction-pump, the pulp solidifies as it advances. The two black squares on either side of the 'dandy' roller, P, indicate the position of two wooden boxes, from which the air is partially exhausted, thus causing the atmospheric pressure to operate in compacting the pulp into paper, the water and moisture being drawn through the wire and the pulp retained on the surface.

Next, we have to notice the deckle or boundary straps, Q, which regulate the width of the paper, travelling at the same rate as the wire, and thus limiting the spread of pulp. The 'dandy' roller, P, is employed to give any impression to the paper that may be required. We may suppose, for instance, that the circumference of that roller answers exactly to the length or breadth of the wire forming a hand-mould, which, supposing such wire to be fixed or curved in that form, would necessarily leave the same impression as when employed in the ordinary way. Being placed between the air-boxes, the paper becomes impressed by it when in a half-formed state, and whatever marks are thus made the paper will effectually retain. The two rollers following the dandy, marked R and O, are termed couching-rollers, from their performing a similar operation in the manufacture of machine-made papers to the business of the coucher in conducting the process by hand. They are simply wooden rollers covered with felt. In some instances, however, the upper couch-roll, R, is made to answer a double purpose. In making writing- or other papers where smalts, ultramarine, and various colours are used, considerable difference will frequently be found in the tint of the paper when the two sides are compared, in consequence of the colouring-matter sinking to the lower side by the natural subsidence of the water, or from the action of the suction-boxes; and, to obviate this, instead of employing the ordinary couch-roll, which acts upon the *upper* surface of the paper, a hollow one is substituted, having a suction-box within it, acted upon by an air-pump, which tends in some measure to counteract the effect justly considered as objectionable. Merging from these rollers, the paper is received from the wire-gauze by a continuous felt, s, which conducts it through two pairs of pressing-rollers, and afterwards to the drying-cylinders. After passing through the first pair of rollers, the paper is carried along the felt for some distance and then turned over, in order to receive a corresponding pressure on the other side, thus obviating the inequality of surface which would otherwise be apparent, especially if the paper were to be employed for books.

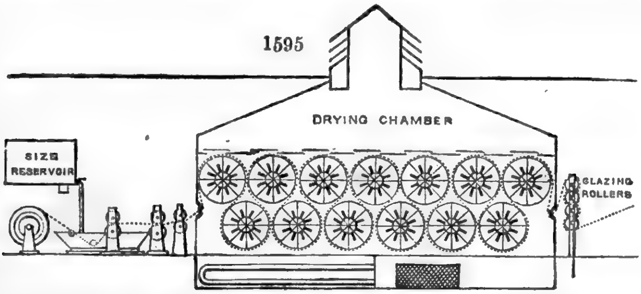
The advantage gained by the use of so great a length of felt is simply that it becomes less necessary to stop the machine for the purpose of washing it, than would be the case if the felt were limited in length to its absolute necessity.

In some instances, when the paper being made is sized in the pulp with such an ingredient as *resin*, the felt becomes so completely clogged in the space of a few hours, that unless a very great and apparently unnecessary length of felt be employed, a considerable waste of time is constantly incurred in washing or changing the felt.

The operation of the manufacture will now be apparent. The pulp flowing from the reservoir into the lifter, and thence through the strainer, passes over a small lip to the continuous wire, being there partially compacted by the shaking motion, more thoroughly so on its passage over the air-boxes, receiving any desired marks by means of the dandy-roller passing over the continuous felt between the first pressing-rollers, then turned over to receive a corresponding pressure on the other side, and from thence off to the drying-cylinders, which are heated more or less by injected steam; the cylinder which receives the paper first being heated less than the second, the second than the third, and so on; the paper, after passing over those cylinders, being finally wound upon a reel, as shown, unless it be printing-paper, which can be sized sufficiently in the pulp by an admixture of alum, soda, and resin, or the like; in which case it may be at once conducted to the cutting-machine, to be divided into any length and width required. But, supposing it to be intended for writing purposes, it has first to undergo a more effectual method of sizing, as shown in the accompanying drawing; the size, in this instance, being made from parings obtained from tanners, curriers, and parchment-makers, as employed in the case of hand-made papers. Of course, sizing in the pulp or in the engine offers many advantages; but as gelatine, or animal size, which is really essential for all good writing qualities, cannot at present be employed during the process of manufacturing by the machine without injury to the felts, it becomes necessary to pass the web of paper, after it has been dried by the cylinders, through this apparatus.

In most cases, however, the paper is at once guided as it issues from the machine, through the tub of size, and is thence carried over the skeleton drums shown, inside each of which are a number of fans rapidly revolving; sometimes there are forty or fifty of these drums in succession, the whole confined in a chamber heated by steam.

1595



A paper-machine, with the sizing-apparatus attached, sometimes measures, from the wire-cloth, where the pulp first flows on, to the cutting-machine at the extremity, no less than 1,000 feet. The advantage of drying the paper in this manner over so many of these drums is, that it turns out much harder and stronger than if dried more rapidly over heated cylinders. Some manufacturers adopt a peculiar process of sizing, which, in fact, answers very much better, and is alike applicable to papers made by hand or by machine, provided the latter description be first cut into pieces or sheets of the required dimensions. The contrivance consists of two revolving felts, between which the sheets are carried under several rollers through a long trough of size; being afterwards hung up to dry upon lines previously to rolling or glazing. The paper thus sized becomes much harder and stronger, by reason of the freedom with which the sheets can contract in drying; and this is mainly the reason why paper made by hand continues to be so much tougher than that made by the machine.

in consequence of the natural tendency of the pulp to contract in drying, and consequently becoming, where no resistance is offered, more entwined and entangled, which of course adds very considerably to the strength and durability of the paper. In making by the machine, this tendency is completely checked.

The following note from a correspondent is well worthy the attention of paper-manufacturers:—

'You are most probably aware that, in the paper-machine, the pulp or half-stuff, after leaving the plane of wire, is pressed between rollers and becomes paper, and then only requires to be made dry and smooth. These objects are effected by the machine conducting the paper over the polished surfaces of large cylinders heated by steam, and afterwards through a series of heavy and highly-polished metal rollers, which are in some cases also heated by steam to increase the effect. Now, a great advantage would be gained by electro-plating those cylinders and rollers with nickel.' (See NICKEL; ELECTRO-METALLURGY.) 'A surface far superior to that of burnished steel would be obtained; being harder than steel, it would not become scratched, and, no rust being formed, it would be always clean and bright. The paper would be found to possess a surface like ivory, the pores being entirely filled up. The only cleaning required, and that at long intervals, would be washing with soap and water, and rubbing with a dry leather. The expense (about ½*d.* per square inch) would be very trifling as compared with that of grinding and re-burnishing; and, if all the bright parts of the machine were electro-plated with nickel, a vast saving of expense in labour would be effected. I am strengthened in these conclusions by the fact, that photographers find that, after passing prints when damp through ordinary steel rollers, an impression is left on them, which, if not cleaned off immediately, causes the steel to rust, and which rust cannot be got rid of without grinding and re-burnishing.'

It may be interesting to mention, that the first experiment for drying paper by means of heated cylinders was made at Gellibrand's calico-printing factory, near Stepney; a reel of paper, in a moist state, having been conveyed there from Dartford in a post-chaise. The experiment was tried in the presence of the patentees of the paper-machine and Mr. Donkin, the engineer, and proved highly satisfactory; and the adoption of copper cylinders, heated by steam, was thenceforward considered indispensable.

The next operation to be noticed, now that the paper is finished, is that of cutting it into standard sizes. Originally, the wheel upon which it was finally wound was formed so that its diameter might be lessened or increased at pleasure, according to the sizes which were required. Thus, for instance, supposing the web of paper was required to be cut into sheets of 18 inches in length, the diameter of the reel would be lessened to 6 inches, and thus the circumference to 18 inches, or, if convenient, it would be increased to 36 inches, the paper being afterwards cut in two by hand with a large knife; the width of the web being regulated by the deckle-straps, Q, to either twice or three times the width of the sheet, as the case might be. However, in regard to the length, considerable waste, of necessity, arose from the great increase in the circumference of the reel as the paper was wound upon it, and to remedy this, several contrivances have been invented. To dwell upon their various peculiarities, or separate stages of improvement, would prove of little comparative interest to the general reader; it will, therefore, be well to limit attention to the cutting-machine, of which an illustration is given (*fig.* 1596), which is unquestionably the best, as well as the most ingenious, invention of the kind.

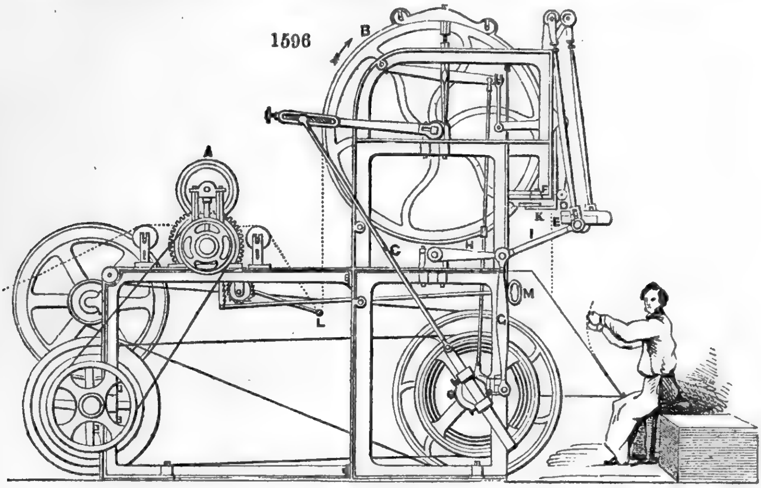
The first movement or operation peculiar to this machine is that of cutting the web of paper longitudinally into such widths as may be required; and this is effected by means of circular blades, placed at stated distances, which receive the paper as it issues direct from the other machinery, and, by a very swift motion, much greater than that at which the paper travels, slit it up with unerring precision wherever they may be fixed.

A pair of those circular blades is shown in the drawing, A (*fig.* 1596), the upper one being much larger than the lower, which is essential to the smoothness of the cut. And not only is the upper blade larger in circumference, but it is also made to revolve with much greater rapidity by means of employing a small pinion, worked by one at least twice its diameter, which is fixed upon the same shaft as the lower blade, to which the motive-power is applied. The action aimed at is precisely such as we obtain from a pair of scissors.

The web, as it is termed by the paper-maker, being thus severed longitudinally, the next operation is that of cutting it off into sheets of some particular length horizontally; and to do this requires a most ingenious movement. To give a very general idea of the contrivance, the dotted line represents the paper travelling on with a rapidity in some cases of 80 feet per minute, and yet its course has to be temporarily arrested while the required separation is effected, and that, too, without the paper accumulating in any mass, or getting creased in the slightest degree.

The large drum, B, over which the paper passes in the direction indicated by the arrows, has simply an alternating motion, which serves to gather the paper in such lengths as may be required; the crank arm, C, which is capable of any adjustment either at top or bottom, regulating the extent of the movement backwards and forwards, and thus the length of the sheet. As soon as the paper to be cut off has passed below the point D, at which a *presser* is suspended, having an alternating motion given to it in order to make it approach to, and recede from, a stationary presser-board, it is taken hold of as it descends from the drum, and the length pendant from the presser is instantly cut off by the moveable knife, E, to which motion is given by the crank F, the connecting-rod G, the lever H, and the connecting-rod I. The combined motion of these rods and levers admits of the moveable knife, E, remaining nearly quiescent for a given time, and then speedily closing upon the fixed knife, K, cutting off the paper in a similar manner to a pair of shears, when it immediately slides down a board, or, in some instances, is carried along a revolving felt, at the extremity of which several men or boys are placed to receive the sheets, according to the number into which the width of the web is divided.

1596



As soon as the pressers are closed for a length of paper to be cut off, the motion of the gathering-drum is reversed, smoothing out the paper upon its surface, which is now held between the pressers; the tension-roll, L, taking up the slack in the paper as it accumulates, or rather gently bearing it down, until the movement of the drum is again reversed to furnish another length. The handle, M, is employed merely to stop a portion of the machinery, should the water-mark not fall exactly in the centre of the sheet, when by this means it can be momentarily adjusted.

The paper being thus made, and cut up into sheets of stated dimensions, is next looked over, and counted out into quires of 24 sheets, and afterwards into reams of 20 quires, which subsequently are carefully weighed, previously to their being sent into the market.

Connected with the manufacture of paper, there is one point of considerable interest and importance, and that is, what is commonly, but erroneously, termed the *water-mark*, which may be noticed in the 'Times' newspaper, in the Bank of England notes, cheques, and bills, as also in every postage- and receipt-stamp of the present day.

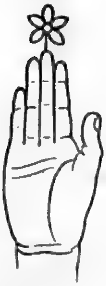
The curious, and in some instances absurd terms, which now puzzle us so much in describing the different sorts and sizes of paper, may frequently be explained by reference to the various paper-marks which have been adopted at different periods. In ancient times, when comparatively few people could read, pictures of every kind were much in use where writing would now be employed. Every shop, for instance, had its sign, as well as every public-house, and those signs were not then, as they often are now, only painted upon a board, but were invariably actual models of the thing which the sign expressed—as we still occasionally see some such sign as a beehive, a tea-canister, or a doll, and the like. For the same reason, printers employed some device, which they put upon the title-pages and at the end of their books; and paper-makers also introduced marks, by way of distinguishing the paper of their manufacture from that of others; which marks, becoming common, naturally gave their names to different sorts of paper. And, since names often remain long after the origin of them is forgotten and circumstances are changed, it is not surprising to find the old names still in use, though in some cases they are not applied to the same things which they originally denoted. One of the illustrations of ancient water-marks given in the accompanying plate, that of an open hand with a star at the top, which was in use as early as 1530, probably gave the name to what is still called *hand* paper, *fig.* 1597.

Another very favourite paper-mark, at a subsequent period, 1540–60, was the jug or pot, which is also shown, *fig.* 1598, and would appear to have originated the term *pot* paper.

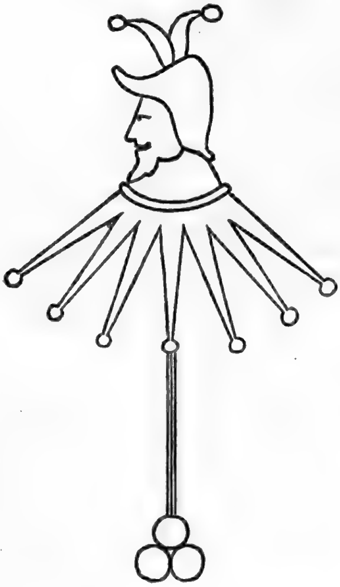
The fool's-cap was a later device, and does not appear to have been nearly of such long continuance as the former, *fig.* 1599. It has given place to the figure of Britannia, or that of a lion rampant supporting the cap of liberty on a pole. The name, however, has continued, and we still denominate paper of a particular size by the title of *foolscap*. The original figure has the cap and bells, of which we so often read in old plays and histories as the particular head-dress of the fool, who at one time formed part of every great man's establishment.

The water-mark of a *cap* may sometimes be met with of a much simpler form than just mentioned—frequently resembling the jockey-caps of the present day, with a trifling ornamentation or addition to the upper part. The first edition of 'Shakespeare,' printed by *Isaac Jaggard and Ed. Blount*, 1623, will be found to contain this mark, interspersed with several others of a different character. No doubt the general use of the term *cap* to various papers of the present day owes its origin to marks of this description.

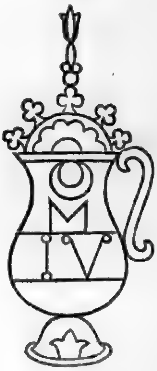
1597



1599

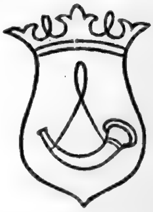


1598



1601

1600



The term *imperial* was in all probability derived from the finest specimens of papyri, which were so called by the ancients.

Post paper seems to have derived its name from the post-horn, which at one time was its distinguishing mark, *fig.* 1600. It does not appear to have been used prior to the establishment of the General Post-office (1670), when it became the custom to blow a horn, to which circumstance no doubt we may attribute its introduction. The mark is still frequently used, but the same change which has so much diminished the number of painted signs in the streets of our towns and cities, has nearly made paper-marks a matter of antiquarian curiosity; the maker's name being now generally used, and the mark, in the few instances where it still remains, serving the purpose of mere ornament, rather than that of distinction.

Water-marks, however, have at various periods been the means of detecting frauds, forgeries and impositions, in our courts of law and elsewhere, to say nothing of the protection they afford in the instances already referred to, such as bank notes, cheques, receipt, bill, and postage-stamps. The celebrated Curran once distinguished himself in a case which he had undertaken by shrewdly referring to the water-mark, which effectually determined the verdict. And another instance, which may be introduced in the form of an amusing anecdote, occurred once at Messina, where the monks of a certain monastery exhibited, with great triumph, a letter as being written by the Virgin Mary with her own hand. Unluckily for them, however, this was not, as it easily might have been, written upon the ancient papyrus, but on paper made of rags. On one occasion a visitor, to whom this was shown, observed, with affected solemnity, that the letter involved also a *miracle*, for the paper on which it was written was not in existence until several centuries after the mother of our Lord had died.

A further illustration of the kind occurs in a work entitled 'Ireland's Confessions,' which was published respecting his fabrication of the Shakspeare manuscripts,—a literary forgery even still more remarkable than that which is said to have been perpetrated by Chatterton, as Rowley's Poems.

The interest which at the time was universally felt in this production of Ireland's may be partially gathered from the fact, that the whole of the original edition, which appeared in the form of a shilling pamphlet, was disposed of in a few hours; while so great was the eagerness to obtain copies afterwards, that single impressions were sold in an auction-room at the extravagant price of a guinea.

This gentleman tells us, at one part of his explanation, that the sheet of paper which he used was the outside of several others, on some of which accounts had been kept in the reign of Charles the First; and being at that time wholly unacquainted with the water-marks used in the reign of Queen Elizabeth, 'I carefully selected (says he) two half-sheets, not having any mark whatever, on which I penned my first effusion.' A few pages further on, he writes—'Being thus urged forward to the production of more manuscripts, it became necessary that I should possess a sufficient quantity of old paper to enable me to proceed; in consequence of which I applied to a bookseller, named Verey, in Great May's Buildings, St. Martin's Lane, who, for the sum of five shillings, suffered me to take from all the folio and quarto volumes in his shop the fly-leaves which they contained. By this means I was amply stored with that commodity; nor did I fear any mention of the circumstance by Mr. Verey, whose quiet unsuspecting disposition, I was well convinced, would never lead him to make the transaction public, in addition to which he was not likely even to know anything concerning the supposed Shakspearian discovery by myself, and even if he had, I do not imagine that my purchase of the old paper in question would have excited in him the smallest degree of suspicion. As I was fully aware, from the variety of water-marks which are in existence at the present day, that they must have constantly been altered since the period of Elizabeth, and being for some time wholly unacquainted with the water-marks of that age, I very carefully produced my first specimens of the writing on such sheets of old paper as had no mark whatever. Having heard it frequently stated that the appearances of such marks on the papers would have greatly tended to establish their validity, I listened attentively to every remark which was made upon the subject, and from thence I at length gleaned the intelligence that a jug was the prevalent water-mark of the reign of Elizabeth, in consequence of which I inspected all the sheets of old paper then in my possession, and having selected such as had the jug upon them, I produced the succeeding manuscripts upon these, being careful, however, to mingle with them a certain number of blank leaves, that the production on a sudden of so many water-marks might not excite suspicion in the breasts of those persons who were most conversant with the manuscripts.'

Thus, this notorious literary forgery, through the cunning ingenuity of the perpetrator, ultimately proved so successful as to deceive many learned and able critics of the age. Indeed, on one occasion a kind of certificate was drawn up, stating that the undersigned names were affixed by gentlemen who entertained no doubt whatever as to the validity of the Shakspearian production, and that they voluntarily gave such public testimony of their convictions upon the subject. To this document several names were appended by persons as conspicuous for their erudition as they were pertinacious in their opinions.

The water-mark in the form of a letter *p*, of which an illustration is given, *fig.* 1601, was taken from Caxton's well-known work, 'The Game of the Chesse,' a *fac-simile* of which has been published as a tribute to his memory. Paper was made expressly for the purpose, in exact representation of the original, and containing this water-mark, which will be found common in works printed by him.

The ordinary mode of effecting such paper-marks as we have been describing is that of affixing a stout wire in the form of any object to be represented to the surface of the fine wire-gauze, of which the hand-mould, or machine dandy roller is constructed.

The perfection, however, to which water-marks have now attained, which in many instances is really very beautiful, is owing to a more ingenious method which has been patented, and is adopted by the Bank of England, as affording considerable protection to the public in determining the genuineness of a bank-note.

To produce a line water-mark of any autograph or crest, we might either engrave the pattern or device first in some yielding surface, precisely as we should engrave a copper-plate for printing, and afterwards, by immersing the plate in a solution of sulphate of copper, and electrotyping it in the usual way, allow the interstices of the engraving to give as it were a casting of pure copper, and thus an exact representation of the original device, which, upon being removed from the plate, and affixed to the surface of the wire-gauze forming the mould, would produce a corresponding impression in the paper; or, supposing perfect identity to be essential, as in the case of a bank-note, we might engrave the design upon the surface of a steel die, taking care to cut those parts in the die deepest which are intended to give greater effect in the paper, and then, after having hardened, and otherwise properly prepared the die, it would be placed under a steam-hammer or other stamping apparatus, for the purpose of producing what is technically termed a 'force,' which is required to assist in transferring an impression from the die to a plate of sheet brass. This being done, the die with the mould-plate in it, would next be taken to a perforating or cutting machine, where the back of the mould-plate—that is, the portion which projects above the face of the die—would be removed, while that portion which was impressed into the design engraven would remain untouched, and this being subsequently taken from the interstices of the die and placed in a frame upon a backing of fine wire-cloth, becomes a mould for the manufacture of paper of the pattern which is desired, or for the production of any water-mark, autograph, crest, or device, however complicated.

Light and shade are occasioned by a very similar process, but one which perhaps requires a little more care, and necessarily becomes somewhat more tedious. For instance, in the former case the pulp is distributed equally throughout the entire surface of the wire forming the mould, whereas *now* we have to contrive the means of increasing to a very great nicety the thickness or distribution of the pulp, and at the same time to make provision for the water draining away. This has been accomplished by first taking the electrotype of the raised surface of any model or design, and again from that, forming in a similar manner a matrix or mould, both of which are subsequently mounted upon lead or gutta-percha, in order that they may withstand the pressure which is required to be put upon them in giving impression to a sheet of very fine copper wire-gauze, which, in the form of a mould, and in the hands of the vatman, suffices ultimately to produce those beautiful transparent effects in paper-pulp. The word 'Five' in the centre of the Bank of England note is produced in the same manner. The deepest shadows in the water-mark being occasioned by the deepest engraving upon the die, the lightest, by the shallowest, and so forth; the die being employed to give impression by means of the stamping press and 'force' to the fine wire-gauze itself, which by this means, providing the die be properly cut, is accomplished far more successfully than by any other process, and with the additional advantage of securing perfect identity.

It may be interesting to call attention to the contrast as regards the method of mould-making originally practised and that which has since been adopted by the Bank of England. In a pair of five-pound note moulds, prepared by the old process, there were 8 curved borders, 16 figures, 168 large waves, and 240 letters, which had all to be separately secured by the finest wire to the waved surface. There were 1,056 wires, 67,584 twists, and the same repetition where the stout wires were introduced to support the under surface. Therefore, with the backing, laying, large waves, figures, letters, and borders, before a pair of moulds was completed, there were some hundreds of thousands of stitches, most of which are now avoided by the new patent. But further, by this multitudinous stitching and sewing, the parts were never placed precisely in the same position, and the water-mark was consequently never identical. Now, the same die gives impression to the metal which transfers it to the water-mark, with a certainty of identity unattainable before, and one could almost say, never to be surpassed.

And may we not detect principles in this process which are not only valuable to the Bank, but to all public establishments having important documents on paper, for what can exceed the value of such a test for discovering the deceptions of dishonest men? One's signature, crest, or device of any kind, rendering the paper exclusively one's own, can now be secured in a pair of moulds, at the cost merely of a few guineas.

Manufactured paper, independently of the miscellaneous kinds, such as blotting, filtering, and the like, which are rendered absorbent by the free use of *woollen* rags, may be divided into three distinct classes, *viz.* writing, printing, and wrapping. The former again into *five*, cream-wove, yellow-wove, blue-wove, cream-laid, and blue-laid. The printing into *two*, laid and wove; and the latter into *four*, blue, purple, brown, and whited-brown, as it is commonly termed.

To obtain a simple definition of the mode adopted for distinguishing the various kinds, we must include, with the class denominated *writing* papers, those which are used for drawing, which being sized in like manner, and with the exception of one or two larger kinds, of precisely the same dimensions as those passing by the same name, which are used strictly for writing purposes (the only distinction, in fact, being, that the drawings are cream-wove, while the writings are laid), there would of course be no necessity for separating them. Indeed, since many of the sizes used for printing are exactly the same as those which would be named as writing papers, for the sake of abridgment we will reduce the distinctions of difference to but two heads, *fine* and *coarse*; under the latter, including the ordinary brown papers, the whited-brown, or small-hand quality, and the blues and purples used by grocers. The smallest size of the fine quality, as sent from the mill, measures 12½ by 15 inches, and is termed pot; next to that foolscap, 16½ by 13½; then post, 18¾ by 15¼; copy, 20 by 16½; large post, 20¾ by 16½; medium post, 18 by 22½; sheet-and-third foolscap, 22½ by 13¼; sheet-and-half foolscap, 24½ by 13¼; double foolscap, 27 by 17; double pot, 15 by 25; double post, 30½ by 19; double crown, 20 by 30; demy, 20 by 15½; ditto printing, 22½ by 17¾; medium, 22 by 17½; ditto printing, 23 by 18½; royal, 24 by 19; ditto printing, 25 by 20; super-royal, 27 by 19; ditto printing, 21 by 27; imperial, 30 by 22; elephant, 28 by 23; atlas, 34 by 26; columbia, 34½ by 23½; double elephant, 26¾ by 40; and antiquarian, 53 by 31. The different sizes of letter- and note-paper ordinarily used are prepared from those kinds by the stationer, whose business consists chiefly in smoothing the edges of the paper, and afterwards packing it up in some tasteful form, which serves to attract attention.

Under the characteristic names of coarse papers may be mentioned: Kent cap, 21 by 18; bag cap, 19½ by 24; Havon cap, 21 by 26; imperial cap, 22½ by 29; double 2-lb., 17 by 24; double 4-lb., 21 by 31; double 6-lb., 19 by 28; casing of various dimensions, also cartridges, with other descriptive names, besides middle hand, 21 by 16; lumber hand, 19½ by 22½; royal hand, 20 by 25; double small hand, 19 by 29; and of the purples, such significations as copy loaf, 16¾ by 21¾, 38-lb.; powder loaf, 18 by 26, 58-lb.; double loaf, 16½ by 23, 48-lb.; single loaf, 21½ by 27, 78-lb.; lump, 23 by 33, 100-lb.; Hambro', 16½ by 23, 48-lb.; titler, 29 by 35, 120-lb.; Prussian or double lump, 32 by 42, 200-lb.; and so forth, with glazed boards of various sizes, used chiefly by printers for pressing, which are manufactured in a peculiar manner by hand, the boards being severally composed of various sheets made in the ordinary way, but turned off the mould one sheet upon another, until the required substance be attained; a felt is then placed upon the mass and another board formed. By this means the sheets, when pressed, adhere more effectually to each other, and the boards consequently become much more durable than would be the case if they were produced by pasting. Indeed, if any great amount of heat be applied to pasteboards, they will split, and be rendered utterly useless. The glazing in this case is accomplished by friction.

To complete the category of coarse papers must be mentioned milled boards, employed in bookbinding, of not less than 150 descriptions, as regards sizes and substances. Still, however, an incomplete idea is conveyed of the extraordinary number of sizes and descriptions into which paper is at present divided. For instance, we have said with reference to writing qualities, that there are *five* kinds, cream-wove, yellow-wove, blue-wove, cream-laid, and blue-laid; and again, that of each of those kinds there are numerous sizes; but in addition there are, as a matter of course, various thicknesses and makes of each size and kind. In fact, no house in London, carrying on the wholesale stationery trade, is without a thousand different sorts; many keep stock of twice that number.[1]

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[1] For further information upon this point, see the 'Practical Guide to the Varieties and Relative Values of Paper.' Longman & Co.

The quantity of paper manufactured in this country at the commencement of the eighteenth century appears to have been far from sufficient to meet the necessities of the time. Even in 1721 it is supposed that there were but about 300,000 reams of paper annually produced in Great Britain, which were equal merely to two-thirds of the consumption. But in 1784, the value of the paper manufactured in England alone is stated to have amounted to 800,000*l.*; and that, by reason of the increase in price, as also of its use, in less than twenty years it nearly doubled that amount.

It may be well to append some extracts from various Parliamentary returns relating to the Excise duties levied upon paper:—

In one return, specifying the rates of duty and amount of duty received upon each denomination of paper since 1770, it appears that the total amount of duty on paper manufactured in England for the year 1784 was 46,867*l.* 19*s.* 9¼*d.*, the duty at that time being divided into seven distinct classes or rates of collection; while twenty years after, when the mode of assessing the duty was reduced to but three classes, it had risen to 315,802*l.* 4*s.* 8*d.*; in 1830, fifteen years after, to 619,824*l.* 7*s.* 11*d.*; in 1835, for the United Kingdom, to 833,822*l.* 12*s.* 4*d.*, or, in weight, to 70,655,287 lbs., which was, again, within so short a period as fifteen years, very nearly doubled. Since 1859 it has not been possible to collect any exact information as to the quantity of paper made; with the cessation of the duty all means of obtaining returns ceased.

The latest returns of the paper-mills in working order in England give the number as 272; the mills in Scotland as 57; and those in Ireland as 21.

The character of the production in the English mills is given as follows:—

Making writing papers (hand-made)	21
,, ,, ,, (machine-made)	22
,, Printing News and Long Elephants	96
,, Cartridges	29
,, Grocery papers (white and coloured)	48
,, Small hands and caps	50
,, Browns	108

Considering the enormous extent of the paper-manufacture, and the vast improvements which have taken place in connection therewith, it is not a little remarkable that, with the exception of the unfortunate Fourdriniers, who sacrificed their all to present to mankind the bare principles of the art, as in the main they now exist, no other name should rest upon the page of history as being similarly associated with those many introductions and improvements which have successively raised the paper-manufacture to the apparently perfect standard which it has at length attained. It is true there would be no difficulty in recording the names of very many who, by the employment of the wealth which they have inherited, are now altogether unsurpassed as paper-manufacturers; and it is equally true that if we turn to the Reports of the Jurors of the Great Exhibition of 1851, we shall find many other names more or less distinguished by the greater or lesser importance of the materials or means for which they have themselves applied for and obtained the security of a patent. Still we search in vain for any name upon record as indicating the true genius to whom is chiefly owing the surpassing beauty of the finest specimens of the paper fabric.

Undoubtedly the most enterprising and successful paper-manufacturer of his day was Mr. William Joynson, of St. Mary Cray, Kent, who by individual effort succeeded in working his upward way from a poor and uneducated journeyman, in a humble paper-mill, to the level of the most respected, and probably the most wealthy of paper-manufacturers.

But Mr. Joynson, distinguished as he was for the superior finish of his writing papers, was not the originator of the process by which that finish was attained. At the cost of much time and some thousands of pounds, Mr. Joynson laboured to acquire a knowledge of the means by which that peculiar character and surface was so successfully accomplished, which, it is said, was first given to writing papers at the Hele paper-mills, near Collumpton, Devon, by the late Mr. John Dewdney. Not only in this respect, but in many others, Mr. Dewdney rendered very distinguished service to the art of paper-making; probably no man more so, and yet throughout his entire life as a paper-manufacturer he never once patented a single invention, or refused admitting to his mill any person who wished to go over it. Whether the same kind-hearted and generous spirit that appears uniformly to have prompted Mr. Dewdney in the conduct of his business would be consistent now-a-days, many may question, as indeed in practice most do; but with Mr. Dewdney it certainly answered no bad end, for after acquiring a competency for himself and each member of a large family, he quietly retired from the paper-manufacture; and in the early part of the year 1852, immediately after the Commissioners of the

Great Exhibition had awarded him a prize medal 'for the excellence of his writing papers, and also for the permanent dye of his blue papers for the use of starch manufacturers,' he disposed of his well-known mills and everything connected with them, to his old friend and competitor, Mr. Joynson, to whom to the last day of his life he continued warmly attached, and by whom he was ever consulted upon the various alterations and inventions which were adopted at St. Mary Cray.

The circumstances of Mr. Dewdney's decease formed a painful coincidence at the close of so remarkably energetic and useful a career. He it was who first introduced a steam-engine for paper-manufacture into the county of Devon; and at the Hele Station, adjoining the Hele mills, almost on the same spot where thirty years previously he reared his engine for manufacture, the engine of the express train from Bristol to Exeter struck him dead.

Another method of making paper, which was invented by Mr. Dickinson, consists in causing a polished hollow brass cylinder, perforated with holes or slits, and covered with wire-cloth, to revolve over and in contact with the prepared pulp. The cylinder being connected with a vessel from which the air has been exhausted, the film of pulp adheres to the hollow cylinder. It is then turned off continuously upon a solid one covered with felt, upon which it is condensed by the pressure of a third revolving cylinder, and is thence delivered to the drying rollers. This description of machine is not suitable for the manufacture of any paper requiring strength. Indeed, throughout the United Kingdom there are probably not more than a dozen in work, and those chiefly in the manufacture of thin tissue papers.

Since 1865 our *Imports* of papers and materials for paper, and our *Exports* of paper have been as follow:—

Importations of Paper for Printing or Writing:

1865	1866	1867	1868	1869	1870	1871	1872
cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
143,524	159,008	174,429	177,220	169,274	173,616	158,885	205,510

Importation of Rags and Paper-making materials:

tons	tons	tons	tons	tons	tons	tons	tons
18,368	24,408	19,201	17,902	17,027	22,394	26,868	22,254

Importations of Esparto and other materials:

52,788	70,586	55,972	96,539	89,156	110,389	154,357	115,157

Exportations of Paper other than Hangings:

cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
145,262	210,892	200,632	186,597	214,933	177,683	228,894	303,293

The *Imports* of paper for printing or writing made in 1873 were 195,336 cwts.; and in 1874, 192,200 cwts.

PAPER-BOX MAKING MACHINE. Among the most novel pieces of mechanical construction recently brought to public notice must be reckoned the machines invented by Mr. H. R. Heyl, Philadelphia, for making paper-boxes, and for the first time publicly exhibited at a recent monthly meeting of the Franklin Institute. The machines in question are the result of years of patient labour and perseverance, and the inventor is deserving of all praise for having so completely and efficiently triumphed over many difficulties. He has in the past seven years built three machines for making paper-boxes, the last and most perfect of which has just been completed, and is the one referred to as having been placed on exhibition. As to the usefulness of machinery to produce paper-boxes with greater rapidity and economy than by hand labour, little need be said, since a simple enumeration of the various branches of industry in which they are indispensable, affords superabundant evidence of their great utility—viz., perfumery, jewellery, hardware, trimmings, matches, and a host of other branches.

The first machine constructed by Mr. Heyl for this purpose was adapted to the automatic shaping, and fastening by paste, of the usual rectangular box, varying the style according to the materials used. The capacity of this machine is 2,000 boxes in ten hours—a capacity which is equivalent to the duty of ten of the most expert workmen employed during the same time.

The second machine has for its object the production of boxes for various purposes without the use of paste, the fastening of the edges of the paper being accomplished by delicate pieces of iron wire, measured and shaped by the machine into miniature staples, which are pressed through the material and clinched at the proper instant. The primary design of this second machine was the production, at rapid rate and cheaply, of match-boxes and other cheap receptacles for tacks, screws, and various small articles; and the substitution of wire-fastenings for the paste, besides greatly increasing the *duty* of the machine, is quite a desideratum on other accounts. It is said by those familiar with the details of such trades, that the delay in drying the boxes when pasted, which often occurs in damp weather, frequently interferes with the shipment of large invoices of goods; in some cases of protracted damp weather, the paper-boxes really mildew before they dry, and might ruin or seriously damage the goods packed in them. It was to obviate these obvious, but to others insuperable, difficulties, that the inventor has produced the wire-fastening machine we have alluded to. The work accomplished by it is not only neater and stronger than that done by hand, but the rate of production of one machine is that of seventy-five workmen. The method of fastening the edges of the paper with wire staples is as follows:—The wire is wound on a spool, from which the proper lengths are drawn by the machine for each box; the staples are formed and brought each to its place, at right angles with the box material, and are made at the proper moment to puncture it, upon which they are, an instant later, firmly clinched on the opposite surface, The power of impact exerted at right angles with an opposing surface is here beautifully illustrated; and be it remembered, that the entire production of the box is to be ascribed to the machine, every portion of the work being automatic. The machine sizes the slips of wrapper singly, and shapes them, and throws out a match-box complete—even to being touched with glue and sprinkled with sand—at the rate of 30,000 pieces per day of ten hours.

The third machine is simply a modified form of the one just described, in which its metallic fastenings and general movements are applied to the production of rectangular boxes of superior quality and of various sizes, applicable for safe packages and display of articles of luxury, &c. The completion of these machines is a realisation of the labour of seven years, and they are now busily plying their functions with perfect success.

The invention of the paper-box machine, by which the supply of articles indispensable to many of the small-ware producers is vastly increased and cheapened, cannot fail speedily to result in the complete substitution of machine-labour for the hand-labour formerly universally employed for the purpose; while, from its perfect adaptation to the uses for which it is designed, and the mechanical ingenuity displayed in its conception and design, it is worthy of all praise.

PAPIER-MÂCHÉ. The fine old philosopher Boyle says:—

'Though paper be one of the commonest bodies that we use, there are very few that imagine it is fit to be employed other ways, in writing and printing, or wrapping up of other things, or about some such obvious piece of service; without dreaming that frames of pictures, and divers fine pieces of embossed work, with other curious moveables, may, as trial has informed us, be made of it.'

The origin of the manufacture of articles for use or ornament from paper, is not very clearly made out; we are naturally led to believe, from the name, that the French must have introduced it. We find, however, a French writer ascribes the merit of producing paper ornaments, to the English. After describing some peculiar ornamental work, the writer proceeds:—

As this work had to be done on the spot, and with much rapidity of execution, in order to prevent the stucco from setting before it had acquired the intended form, the art was somewhat difficult; the workman had to design almost as he worked; therefore, to do it well, it was necessary that he should have some of the requirements and qualities of an artist. This circumstance, of course, tended very much to limit the number of workmen, and their pay became proportionally large. The artisans assumed more than belonged to their humble rank in life, and ultimately the workers in stucco combined together to extort from their employers a most inordinate rate of wages. It would be superfluous here to detail all that followed; it is sufficient to state that the total ruin of their art was the final result of these delusive efforts to promote their individual interests.

Contrivances were resorted to by the masters which soon supplanted the old mode of working in stucco. The art of moulding and casting in plaster, as previously practised in France, was generally introduced, and the art of preparing the *pulp of paper* became improved and extended, so as ultimately to render practicable the adoption of papier-mâché in the formation of architectural decorations. Thus, at last, was extinguished the original mode of producing stucco ornaments, and there probably has not been for many years a single individual in England accustomed to that business.

From the 'Gentleman's Magazine,' we learn that many of the fine old ceilings in deep relief of the Elizabethan era are of papier-mâché. The handsome ceilings in Chesterfield House are of this material.

A kind of papier-mâché has been introduced, called *fibrous slab*; for the preparation of this interesting material the coarse varieties of fibre only are required. These are heated and subjected to much agitation, to secure the reduction of the fibre to the proper size. This being effected, the pulp is removed and subjected to the action of the desiccating apparatus, or centrifugal drying machine. By the means of this apparatus the water is driven, by the action of the centrifrugal force, from the fibre, and the pulp can thus be obtained in a few minutes of an equal and proper degree of dryness, and this without the application of any heat. The mass thus obtained may be regarded as a very coarse mixture.

This fibrous pulp is next combined with some earthy matter to ensure its solidity, and certain chemical preparations are introduced, for the double purpose of preserving it from the attacks of insects and to ensure its incombustibility. The whole being mixed with a cementing size, is well kneaded together, steam being applied during the process. While the kneading process is going forward, an iron table running on wheels is properly adjusted and covered with a sail-cloth; this table being arranged so that it passes under an immense iron roller. The fibrous mixture is removed from the kneading troughs, and is laid in a tolerably uniform mass upon the sail-cloth, so as to cover about one-half of the table; over this again is placed a length of sail-cloth equal to that of the entire slab, as before. This being done, the table and roller are set in action, and the mass passes between them. It is thus squeezed out to a perfectly uniform thickness, and is spread over the whole table. The fibrous slab is passed through the rollers some three or four times, and it is then drawn off upon a frame fixed upon wheels prepared to receive it, by means of which it can be removed to the drying ground. The drying process of course varies much with the temperature and dryness of the air. It does not appear necessary that these slabs should dry too quickly, and there are many reasons why the process should not be prolonged.

We tried an experiment upon the non-inflammability of this material, by having a fire of wood made upon a slab and maintained there some time. When the ashes, still in a state of vivid combustion, were swept away, the slab was found to be merely charred by the intense heat. Beyond this, a piece of fibrous slab was thrown into the middle of the fire and the flames were urged upon it: under the influence of this intense action it did not appear possible to kindle it into a flame; it smouldered very slowly, the organic matter charring, but nothing more.

The Fibrous Slab Company produced a material which, in many of its applications, promised to prove of the greatest utility, while much additional value was given to it from the circumstance of its resisting the attacks of insects, and being non-inflammable. We believe, however, that this manufacture has been discontinued.

Papier-Mâché may be said, therefore, to consist of three varieties:—1. Sheets of paper pasted together, exposed to great pressure, and then polished; 2. Sheets of considerable thickness, made from ordinary paper-pulp; and 3. Such as we have described in the manufacture of the fibrous slab.—E. J. H.

A new composition was patented, in 1858, by Mr. John Cowdery Martin, which he designated a 'Plastic compound for the manufacture of articles in imitation of wood carvings, &c.' The patentee thus describes his process, and the resulting material:—

'The object I have had in view is the production of a plastic compound applicable to the manufacture of moulded articles, which, when hardened, resembles wood in the closeness of its texture and fibrous character throughout, and is particularly applicable to the manufacture of articles intended to imitate wood-carvings. The new manufacture may also be called *ceramic papier-mâché*, from the wax-like character of the compound when in a soft state, or before hardening. The compound consists of twenty-eight parts (dry) by weight of paper-pulp, or of any fibrous substances of which paper may be made, reduced to pulp by means of an ordinary beating engine, or other means used for the manufacture of pulp; twenty parts of resin, or rosin, or pitch, or other resinous substance. I prefer resin or rosin; ten parts of soda or potash to render the resin soluble; twenty-four parts of glue, twelve parts of drying oil, and one part of acetate or sugar of lead, or other substance capable of hardening or drying oil. The pulp after leaving the beating engine is to be drained and slightly pressed under a screw or other press, to free it partly from water. The resin and alkali are then to be boiled or heated together and well mixed. The glue is to be broken up in pieces and melted in a separate vessel with as much water as will cover it, and then to be added to the resin and alkali, which mixture is then to be added to the pulp and thoroughly incorporated with it. The acetate of lead well mixed in the oil is then to be added, and the whole mass or compound is then to be thoroughly mixed. The quantity of resin and alkali, in proportion to the glue used, might vary, or glue might even be dispensed with when the acetate of lead would be proportionally increased. After mixing the compound, it is to remain exposed to the air for three or four days before using, and to be continually turned to free it from some of its moisture, for the purpose of partially drying, when it is to be well kneaded, and again exposed to the air for a few hours; and this operation of kneading and partial drying may be repeated until the compound is considered to be sufficiently stiff and plastic, as, during the process of kneading or working together, it becomes extremely plastic, resembling from this quality, when sufficiently kneaded, wax or clay, and it may then be worked, pressed, or moulded into any required form. The compound may be kept in a plastic state for some weeks, or even months before using, if required, by keeping it from exposure to the air and occasionally kneading or working it together. The moulds should, previous to pressing therein the compound, be brushed with oil, or with oil in which is mixed a little acetate of lead. The article taken from the mould is to be thoroughly dried, and afterwards it may be baked in an oven at a moderate heat, the temperature to be low at first, and gradually increased, care being taken not to scorch or injure the fibres of the compound. The plastic compound so made and treated acquires many of the peculiarities of wood, as regards hardness and strength, and it may be cut, or carved and polished, if required. Any colour may be added to the compound when in a soft state, or two or more portions of the compound, stained with different colours, may be worked together to form a grain to more nearly imitate the appearance of wood. The use of the alkali being to render the resinous substance sufficiently soluble to combine with the wet pulp, a more or less quantity than that given in proportion to the resin may be used, according to the degree of solubility thought to be necessary. When potash is used, it may be dissolved in water before being heated with the resin. The quantity of glue may vary, and may be increased to twice the quantity of resin, or even more, or sufficiently so as to dispense with the acetate of lead, as it gives hardness, and with oil prevents the compound from sticking; but mixed in this manner it cannot be so well kneaded, and does not retain so fine an impression. I prefer using with the ingredients as above mentioned the acetate of lead; but half a part by weight of a solution of sulphuric or other acid, diluted with twenty times its volume of water, may be substituted for the one part of acetate of lead. The oil mixed with the other ingredients is used to prevent the compound from adhering to the surface of the moulds, but the less oil consistently with this object that is used, the better. Only half the proportion of oil stated to be used as above may be added at the time of mixing the ingredients of the compound, and the remainder may be added during the process of kneading or working up the mass. I wish it to be understood, although I prefer to use resin or rosin or pitch to form the compound, that other resinous bodies soluble with alkalis may be used, as the gums copal, mastic, elemi, lac, Canadian balsam, Venice turpentine, or other resinous bodies of a like kind, either separately, or mixed according to the facility with which they will combine with wet pulp, and the convenience with which the compound may be worked, as will be well understood by persons conversant with these substances.'

PAPIN'S DIGESTER. See DIGESTER.

PARAFFIN; from *parum affinis*, indicating the want of affinity which this substance exhibits to most other bodies.

Paraffin is a white substance, void of taste and smell; it has a specific gravity of 0·87; melts at 112° Fahr., and boils at a higher temperature, with the exhalation of white fumes; it is not decomposed by dry distillation; burns with a clear white flame, without smoke or residuum; and does not stain paper. It is decomposed neither by chlorine, strong acids, alkalis, nor potassium; and mixes by fusion with sulphur, phosphorus, wax, and resin. It dissolves readily in warm fat oils, in cold essential oils, and in ether, but sparingly in boiling absolute alcohol. It has been obtained by the destructive distillation of peat, wax, wood, bones, coal, and shale.

The solid obtained is manufactured into beautiful candles, more than 5,000 tons being employed annually in this manufacture. The lining of beer-barrels, the preserving of jams, fruits, and meats, and waterproofing and softening of fabrics, are some of its patented uses. It may also be used as an insulator. Soft paraffin is much employed in the lucifer-match manufacture. See NAPHTHA; MINERAL CANDLES; PEAT; DESTRUCTIVE DISTILLATION; PETROLEUM.

Paraffin is a generic term for a series of compounds of carbon and hydrogen, in which the hydrogen is in the highest proportion to the carbon in which these elements can unite. Marsh-gas, the lowest member of the series, contains 1 atom carbon to 4 of hydrogen; the other members thence ascend by an addition of CH^2 to very complicated molecules, thus:—

CH^4, marsh-gas or methane;
C^2H^6, ethane;
C^3H^8, propane; and so on.

Brodie obtained two paraffins from bees'-wax; one had C^{27}, and the other C^{30}; while paraffins still higher in the series are known to exist. By removal of two atoms of hydrogen, any member of the series may be removed into that of the olefines: thus, ethane $-2H$ gives olefiant gas. Beginning with highly permanent gases, the paraffin series passes gradually into very volatile liquids, thence through those of less volatility into solids melting a little over ordinary temperature, and up by higher-melting solids to one fusing as high as 176° Fahr. The petroleum of commerce consists entirely of this series; whilst the so-called paraffin oils contain only $\frac{1}{6}$th or $\frac{1}{8}$th part of it, their other constituents being mainly olefines.

The softest of the solid paraffins boil over 600° F.; but those of the highest melting-point only decompose slightly by distillation. Chlorine passed through melted paraffin gradually converts it into a thick clear liquid like castor oil; but, by longer continued action, changes it to a brittle solid. Bromine acts on paraffin when both are heated together in sealed tubes. When equal quantities of sulphur and paraffin are heated together, a current of pure sulphuretted hydrogen is generated. Sulphuric acid, heated to a very high temperature, chars paraffin on contact, with evolution of sulphurous acid. Nitric acid reacts on it, producing an oily nitro-compound, and also acids of the succinic and butyric series.

The manufacture of paraffin and paraffin oils from cannel and shales has now become one of the important branches of national industry. The rapidity of its development is almost unexampled.

At the expiry, in 1861, of the patent of Messrs. Young & Co., a long list of wealthy and influential companies embarked in this new industry, principally in the Bathgate oil district, which has extended throughout nearly the whole of Linlithgow, and encroaches upon Edinburghshire; and the Leeswood oil district in Flintshire. But the great importation of American petroleum brought on a crisis in 1866; and ever since, through various causes, this new manufacture has been dwarfed from its first anticipated gigantic dimensions.

The Scotch oil works are almost exclusively supplied with shales, of which the most important is the Boghead or Torbane Hill mineral, the technical definition of which, whether coal or shale, was once the subject of so warm a controversy. It is found a little to the south of Bathgate. It takes precedence of all the raw materials for the distillation of paraffin and paraffin oils, both historically and in point of richness. It was the material originally worked by Mr. Young, as above described; but the limited basin containing it is now virtually worked out. The other shales of the district vary considerably in richness, both as regards the quantity and quality of the distilled products. See SHALES and MINERAL OILS.

In Flintshire three varieties of material were used: the *curly cannel*, the *smooth cannel*, and the *bottom shale* or 'bastard cannel.' But the high price now given for them by gas-makers has withdrawn the first two minerals from the raw material of the oil-manufacturer. The demonstration of their value as sources of paraffin, &c. is due entirely to the persevering efforts of Mr. W. C. Hussey Jones, during the years of 1861 and 1862, which finally resulted in the formation of the 'Leeswood-Green Cannel and Gas-Coal Company,' and the oil works of Messrs. Fernie & Co., at Leeswood in Flintshire, and at Saltney in Cheshire.

The Leeswood cannel-seam is from 5 to 6 feet thick in the best portions of the basin, which is but of a very limited area, and thins out at its boundaries. The upper portion of the seam consists of the smooth cannel, having a thickness of about 25 to 30 inches; next below is the curly cannel, about 18 inches in thickness; and below this the shale or bastard cannel, which varies considerably, both in thickness and richness. It ranges from about 14 inches to 2 feet in thickness. In some places, especially to the westward of Leeswood, this shale is replaced by a common bituminous coal, which, adhering firmly to the smooth cannels, seriously interferes with its value as a source of burning-oil; the distillate from this coal containing oils of the benzole and naphthaline series, giving red smoky flames. Northward, beyond the river Alyn, and towards Mold, the whole seam thins out to 18 or 24 inches, and contains only smooth cannel.

Besides these, there is a bituminous ironstone similar to the 'black-band ironstone' of Scotland, which comes in irregularly with the bottom shale; and a black shale forming the roof above the smooth. Both of these contain oil, but have not hitherto been regularly worked.

Curly cannel yields upon distillation about 30 per cent. of *crude* oil, of specific gravity varying from 875 to 890; smooth cannel, about 16 per cent. of *crude* oil, of specific gravity from 925 to 940; and the shale, which is very variable, yields from 12 to 15 per cent. of oil, specific gravity about 900.

As cannels yielding a coke are limited in area, and are valuable in gas-making, it is now found commercially unprofitable to use them in oil-making. All the Welsh seams above described, except the lowest one, are no longer put into the retorts;

consequently crude-oil making does not flourish in this, for three years, once busy centre. The Flintshire refiners now look to Scotland for the raw material of their manufacture. Many ingenious retorts designed specially to use cannel, some of which were fully described in a previous edition, are now abandoned.

In the extraction of crude oil, the cannel or shale has to be enclosed in a suitable vessel, subjected to the degree of heat necessary to drive off its condensible vapours, which vapours must pass through an outlet communicating with a suitable condensing apparatus.

This is simple enough; and, for the mere production of paraffin oils from cannel or shale, any kind of pot with an outlet-pipe, heated sufficiently by any kind of fire, will suffice; but to produce the maximum quantity of *condensible* vapours, and the *minimum* quantity of incondensible gas, with the greatest degree of rapidity, and with the smallest amount of outlay in plant, labour, and fuel, is a problem of some practical difficulty.

At first sight, the distillation of crude oil from cannels and shales appears almost identical with gas-making, and, accordingly, the early retorts were simply copies of those found by experience to be most suitable for gas-making.

It soon became understood, however, that some of the most important conditions to be observed are exactly the opposite of those upon which success in gas-making depends. In gas-making the desideratum is to obtain the maximum amount of permanently elastic gas, and the minimum of condensible vapours; in oil-making, we require to reduce the permanent gases to the minimum, or, if possible, to make none, and to obtain in their place the greatest possible quantity of condensible vapours. It is now well known that if these condensible vapours are exposed to a high temperature they are decomposed, and to a considerable extent converted into permanent gas, and that the proportion of permanent gas bears some relation to the excess of temperature; the greater the heat, the more incondensible gas and the less condensible vapours are formed. In gas-making, therefore, a very high temperature is desirable; in oil-making the great object is to subject the coal to no excess of temperature beyond that which is absolutely necessary for its distillation into condensible vapours.

Without dwelling further on obscure theoretical considerations, we may state generally that the practical result of excessive heat is, besides a wasteful production of permanent gas, the production of a crude oil of darker colour, higher specific gravity, and possessing a characteristic odour well known to practical oil-makers as that of 'burnt oil.' This burnt crude oil contains less solid paraffin, and is much more difficult to refine than crude oil made at a lower temperature from like material. It requires much more acid treatment, and even then produces burning-oil, which still retains the 'burnt' odour, and blackens the lamp-glasses.

The difficulties standing in the way of distillation at the proper temperature are: 1, the necessity of decomposing before distillation; 2, the varying boiling-points of the different products; 3, the law of radiation, which demands a higher temperature in the retort than that of coal; and 4, the commercial necessity of rapid working.

We will consider these *seriatim*; and, in describing the improvements and attempted improvements in retorts, refer each to the difficulty that it aims to overcome:—

1. Although these hydrocarbons known as paraffin oils and paraffin are obtained from the cannel by distillation, it is quite clear that they do not exist there as such. We may saturate a mass of the porous cannel coke with these hydrocarbons, or with crude solid paraffin, and produce a flaming coal thereby, which, upon careful distillation, will give back the volatile hydrocarbons; but this artificially-saturated coke is essentially different from the original cannel, as shown by the fact that we may remove the hydrocarbon from the saturated coke by pounding it and washing with a solvent of paraffin, &c., while the cannel itself resists the action of all such solvents. The same is the case with Boghead and paraffin shales generally, though they are not unfrequently described as porous minerals merely saturated with bituminous matter by infiltration. Mr. Gellatley of Bathgate proved this experimentally by converting paraffin into anthracene and naphthaline by passing its vapours through a red-hot tube.

The distillation of cannels and shales is thus a more complex process than the distillation of a volatile oil, a resin, or bitumen. In the latter case the substance is merely raised to its boiling-point, and this heat being maintained its vapour is driven off. In the distillation of coal, the first function of the heat is to overcome the chemical affinities which hold the hydrocarbon elements in the peculiar form in which they exist in the coal, and then after this separation to drive their vapours over. It is a compound process of decomposition and distillation, and the heat has to overcome the combined forces of chemical and cohesive attraction. Hence a considerably higher temperature than that of the mere boiling-point of the resultant hydrocarbons is necessary. Here, then, at the outset we encounter an insuperable necessity for heating the vapours considerably above their boiling-points—to a temperature, in fact, at which some degree of further decomposition must take place, and some amount of permanent gas must be formed.

2. The boiling-points of the different volatile hydrocarbons obtainable from the cannel or shale, range from about 200° to about 500° Fahr. In order to drive off the latter, we are compelled to raise the temperature to about 300° above the boiling-point of the former, exclusive of the excess of heat required for the primary decomposition described under No. 1.

3. When any kind of closed retort or oven is used which is charged internally, and the coal receives its heat from the outside, it is not merely necessary to raise the temperature of the sides of such retort to the decomposing and distillation-heat, but to something above this heat, as no body can give off any heat by radiation or convection to another body unless it be hotter than the body which is to receive the heat. As the quantity of heat communicated by radiation to a given surface varies inversely with the square of the distance from it, this difference of temperature requires to be increased very considerably, as we enlarge the retort in any manner that increases the distance of portions of the coal from its heated surface.

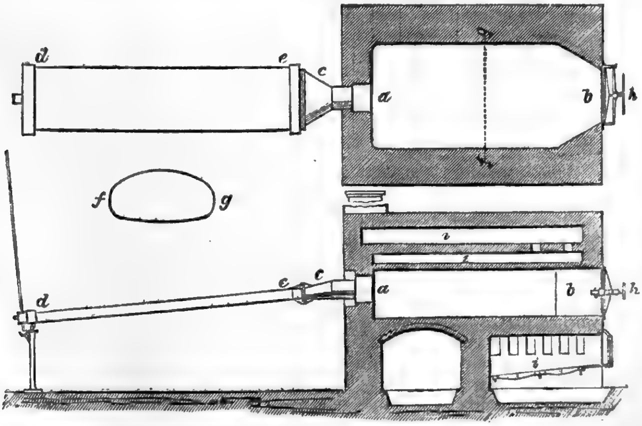
4. The commercial necessity of rapid working, in order to economise original outlay upon plant, drives us to enlarged retorts acting disadvantageously under No. 3, and to exaggerate the excess of temperature of the retort-surface, in order to effect rapid communication of heat.

It will be at once understood that the combined action of these four necessities is to expose the vapour that is formed to the action of the greatly-superheated retort-walls, and thereby decompose it. The primary object of all improvements, beyond those directed to economising labour and plant, is to overcome or diminish these sources of loss and deterioration; and, in describing the different forms of retort, we shall refer to their intent accordingly.

It will be readily seen that the first of these difficulties is insuperable, that the others for the most part can only be partially overcome, and thus that the process is necessarily wasteful to some extent. All crude-oil works until lately presented a painful manifestation of this in the flaring jets of gas that illuminated so vividly the surrounding country. But this waste gas is now utilised in supplying small towns, like Bathgate and West Calder in Scotland, with a cheap illuminant; or in generating heat for the boilers and retorts after the light condensible oil has been suitably removed from it. Young's Company recover in this way a gallon of mineral spirits in every thousand cubic feet of gas generated.

The first step made in Wales beyond using the common gas-retort was to increase greatly the width and diminish the height of the D-retort, and forming thereby the 'flat D,' now very extensively used, and by most manufacturers still regarded as practically the most useful form of retort. As almost every firm has its particular pattern,

1603



we can only state dimensions generally: from 8 to 10 feet is the usual length; width, from 30 inches to 5 feet 6 inches, commonly 3 to 4 feet; and height, from 12 to 24 inches. The verdict of experience runs in favour of further flattening down to the 12 inches.

Fig. 1603 represents the general arrangement of Mr. Birkbeck's flat D's in plan and section, where *a b* is the body of the retort, *c* the outlet-pipe, *d e* the flat condenser, *f g*, transverse section of body of retort at $f'\ g'$, *h* the retort-door and screw-clamp, and *i i i* furnace and flue. These retorts are 5 feet 6 inches wide.

The advantage of such retorts over the D gas-retort is obvious upon consideration of difficulty No. 3. The coal is spread over a larger surface in a thinner layer, and yet a large quantity is included in one charge. All experience goes in favour of spreading out the coal in thin layers rather than packing it in a thick mass. The thinner the layer the smaller will be the difference of temperature between the retort itself and the least heated portion of its contents.

1604

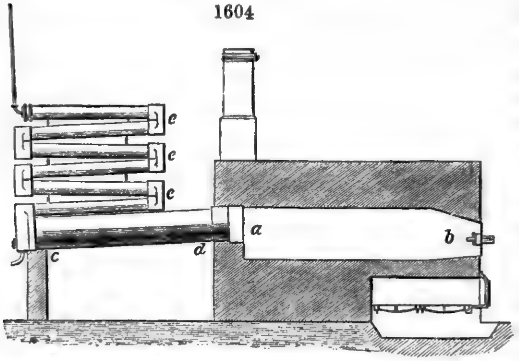


Fig. 1604 represents another form of flat D; *a b*, body of the retort; *c d*, main condenser and outlets; *eee*, zigzag supplementary condenser made of cast spouting pipe. It is made by Bryan Johnson, of Chester.

This retort differs but little from the previous one, excepting in having a large outlet with more direct communication with the condenser, and the modified form of the condenser itself. A large outlet is always advantageous, as by its means the vapours more readily escape from the decomposing action of the heated retort and its contents.

1605

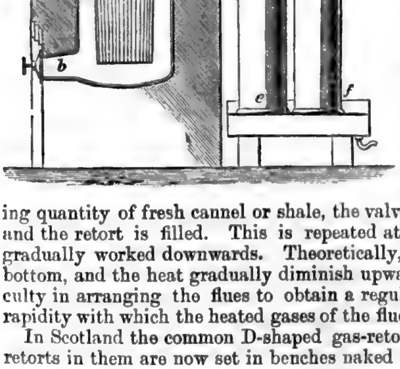


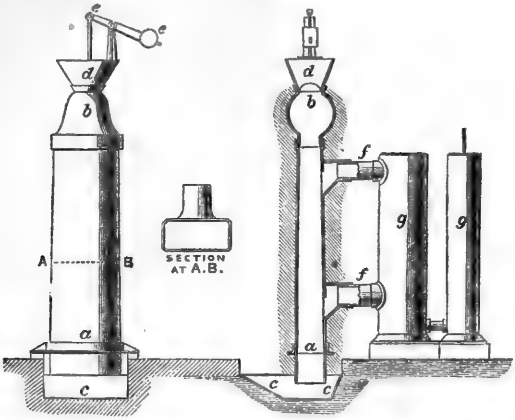
Fig. 1605 represents in section the upright retort of Mr. Holmes of Ruabon, where *a a a* is the body of the retort, *b* the discharging outlet for the coke, *c* the charging mouth, *d* the vapour-outlet, *e e* and *f f* the condensers.

In this retort the internal cage shown in the figure serves the purpose of the shelves, &c. already described, as by its means the charge forms a layer occupying the space *a a a* in contact with the retort-walls, while the vapours pass into the cage and thence to the condenser. It is easily charged where the coal is brought from an upper level.

Fig. 1606 represents Bryan Johnson's modification of the Scotch upright retorts, which work a continuously-descending charge. Supposing the retort to be filled, the valve at *a* is opened, and a portion of the coke let down into the receiving water-tank, *c c*. The hopper, *d*, being filled with a corresponding quantity of fresh cannel or shale, the valve, *b*, is raised by means of the lever *e e*, and the retort is filled. This is repeated at short intervals, and thus the charge is gradually worked downwards. Theoretically, these retorts should be hottest at the bottom, and the heat gradually diminish upwards; but practically there is great difficulty in arranging the flues to obtain a regular gradation of heat on account of the rapidity with which the heated gases of the flues ascend when the draught is at all free.

In Scotland the common D-shaped gas-retort continues in a few crude works. The retorts in them are now set in benches naked to the fire, and the waste gas is also led below them; so that a saving of 4 cwts. of coal in each charge of shale is effected. But, after much controversy, a continuous vertical retort, similar to that in *fig.* 1606, but of a more oval shape is preferred. The merits of the case appear to be that parties desirous of making only crude oil should erect horizontal retorts, whilst refiners making their own *crude* should rely on verticals. The oil from vertical retorts has a

1606



specific gravity of 890°; that from horizontal retorts varies from 850° to 860°; but indeed has been as low as 840°. The latter commands the best price in the market; but the former is more cheaply made by the refiner; and it is more valuable, for though there is less burning-oil and naphtha, it contains 3 per cent. more paraffin. In the Scotch upright retort the distillation is *per ascensum*; and the condensers are simpler than those figured in the drawing; indeed, very complex forms of condensers were used in the first stages of coal-oil making; such as worm-tubes, with water-tanks and hydraulic mains of various patterns. It is now found that simple radiation is a sufficient cooling agent.

Mr. Young of Straiton, near Edinburgh, some years ago introduced a very effective retort resembling somewhat in section *fig.* 1605. But the cage is represented by a framework of impervious iron, round which the waste gases are first conducted away with the other products in this case by distillation *per descensum*, but afterwards reintroduced by a suitable opening play, assisting the small fire. Not only is coal saved, an item of importance even in days of cheap fuel, because such shale works are generally far from coal-pits, but more paraffin is obtained. The Oakbank Oil Company, Midcalder, have used these retorts with great satisfaction.

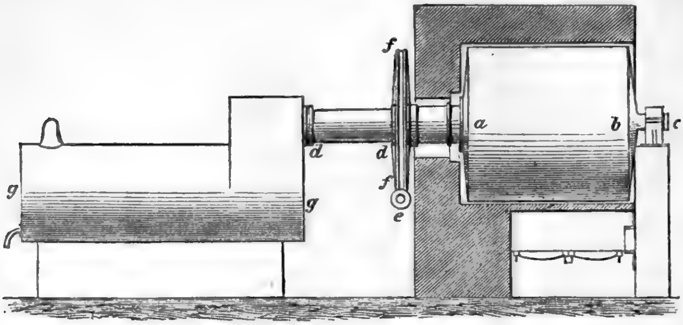
The revolving retort is an American invention. It is shown in elevation and section in *figs.* 1607, 1608, 1609, the lettering being the same in the sections and the elevation.

a a is the body of the retort, a cast-iron cylinder (wrought-iron has also been used) usually about 7 feet diameter and 7 feet long. The cylinder turns on the axles *c* and *d d*; the latter, *d d*, is hollow and serves also as the vapour-outlet to the condenser *g*, which has a second or supplementary condenser shown in section at *h*, connected with the first by the swan-neck *i i* (*fig.* 1608).

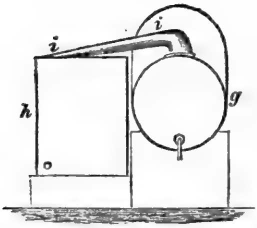
The cylinder or body of the retort is turned very slowly by means of an endless screw, *e*, working in a toothed-wheel, *f f*. The charging door, *k*, is on the opposite face of the cylinder. The heat is communicated from the furnace by means of an arched flue which embraces the whole of the cylinder. To charge the retort the door, *k*, is turned upwards, as shown in the figure; to discharge, it is by a half-revolution from this position brought to the lower side.

The action of these retorts will be easily understood. The charge is continually rolled over, and thus fresh portions are brought in direct contact with the heated surface. By this means a very rapid distillation is effected. In this respect they are most efficient. The objections to them are their costliness in the first place, and their liability to crack, from the unequal expansion of so large a surface of metal. They cannot be protected all round, as ordinary retorts are, by a casing of fire-bricks, and being thus exposed to the direct action of the fire are rapidly destroyed, especially if great care is not taken to remove the lining of carbon-deposit which forms on the inside. When ordinary cannel is used, they have to be cleaned out weekly, which involves a serious loss of time in cooling down and reheating all the surrounding brickwork. This difficulty is to a great extent overcome by working lumps of hard shale with the cannel, which is especially necessary when cannel slack, for which these retorts are best adapted, is used. Where the material to be used is liable to soften and become at all adhesive when treated, these retorts are utterly useless. When it forms a hard clinker coke, they may with careful management be advantageously used, as the quantity of work done by them is very great.

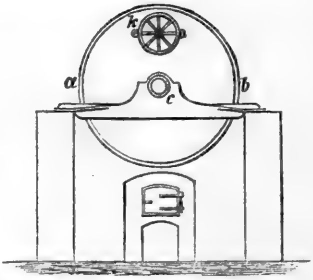
1607



1608



1609



Another difficulty is presented by a very friable material which readily crumbles into dust, as such dust flies over with the vapour and makes a very dirty oil.

Among the earlier efforts to improve the process of distillation of coal, &c., was the application of superheated steam. Several patents have been secured for this, the general object being to drive the heated vapour through a mass of coal broken into small pieces, and thereby apply the heat directly to each fragment, thus completely avoiding the third source of excessive temperature, besides affording an effectual means of regulating the temperature while diffusing it equally throughout the whole mass.

This method, though so admirable in theory, has failed in practice, after being well tried by Messrs. Young, by Messrs. Lavender and Co. at the Canneline Oil Works, Flintshire, and by others. It is now, as far as we are aware, altogether abandoned. The difficulties that have led to its abandonment were mainly the costliness of the superheating process, and the great amount of steam required to be formed in the first place, and then to be condensed. It must be remembered that while the latent heat of steam is equal to about 1000° Fahr., that of the hydrocarbons primarily to be distilled is not above one-tenth of this; thus every pound of steam requires for its condensation about ten times the amount of cooling surface which is necessary for the condensation of a pound of oil-vapour; and the complete condensation of the steam is necessary, as it obstinately retains an important quantity of oil-vapour diffused through it.

The use of heated gases, such as nitrogen, carbonic acid, &c., in the place of steam, overcomes this difficulty; but the cost of preparing the gases renders their application equally impracticable on the primary score of economy.

The 'meerschaum retort' is a modification of the principle of distilling the coal by *internal* application of heat. This is effected by means of a large chamber or kiln, rather than retort, constructed of fire-brick and shaped like a huge tobacco pipe-bowl, with which an exhaust-pipe like the stem of a tobacco-pipe communicates with the bottom. This exhaust-pipe communicates with suitable condensing chambers. The bowl or kiln is charged with the cannel or shale, on the top of which is laid a stratum of burning coke or a mixture of coke and slack. As soon as this upper stratum is in a state of full combustion, the exhaustion is commenced by means of a steam-jet, and the heated products of combustion are drawn down through the charge. That portion immediately below the fire is of course the first acted upon, the action commencing with a distillation of the most volatile products. As the heat increases, the more stubborn and denser vapours are driven downwards through the lower mass, and by their heat commence the distillation there. Subsequently, the upper layer of cannel having all its volatile constituents driven off, becomes a coke, and at this stage is so highly heated as to burn and give off combustion products, viz. carbonic oxide, &c., instead of distillation products, thus serving as fuel for the cannel below, and so on till the mass is coked to the bottom. When this is completed, the steam-jet is turned off, the exhaustion ceases, and the charge is drawn from below, a portion of it being used in its burning state for starting a neighbouring kiln, which should always be charged ready to commence working when its predecessor has reached this stage.

The size of Mr. Holmes' meerschaums is 12 feet high, and 8 feet diameter, internal measurement. They are to be charged to a depth of 10 feet, and to contain 12 tons of cannel.

Mr. Holmes' attempt to introduce this retort in Wales proved disastrous. In 1866, Mc Beth patented an adaptation of the principle to the ordinary Scotch retort [Spec. A.D. 1866, No. 2788]. Very poor shales were worked to profit; but the skill necessary to produce a good product in the daily working proved a serious drawback. Ordinary labour only is requisite for the common retorts. Messrs. Young and Stephens have patented a new retort similar to one already described, but doing without the aid of coal. Suppose four retorts, similar in section to *fig.* 1605, built in a bench, but the bottom of each open, and having attached to each a condensing apparatus, at the extremity of which is a steam-jet. Each cylinder receives a charge of shale which is renewed every 5 hours; a fire of coals is then lighted in the furnace, which begins distillation, at the same time igniting the lower layer of shale: a portion of this falls out into the space betwixt the furnace-wall and the retort and acts instead of coal. The condensers being now filled with vapours, the steam-jet is set in motion, and air is exhausted from the retort, the condensible vapours become crude-oil, and the incondensible gas is returned to play on the walls of the shale cylinders. The oil is of good specific gravity unburnt, very rich in paraffin, and equal in yield to the ordinary retorts. No coal is necessary, except when the distillation begins either at the commencement of the works or after a shut-down. Other inventors are busy on the problem, in making the material giving the valuable paraffin yield power for its extraction. On this solution mainly rests the possibility of our shale-oil manufacturers competing successfully with the petroleum from the American springs; and also of a more extended use of solid paraffin for many new processes in the arts. For the production of solid paraffin, a bye-product in mineral-oils when burning-oil brought 1*s.* 6*d.* to 3*s.* 6*d.* per gallon, is now a main source of income, when the former main product only brings 1*s.* per gallon or less nett at the works.

Boghead and the cannels usually yield from 1 to 1·4 per cent. of paraffin scales of raw materials used; Scotch shales, in ordinary manufacture, 3 to 4 per cent. But individual shales are known yielding a very large percentage of this substance, which, unlike the burning-oils, increases in commercial value. When bodies are worked for this alone, much of the expense of an oil-refinery will be saved; and the resulting oils in their manufacture may be sold almost at the price of waste substances.

Paraffin refiners receive supplies of their raw material from other natural sources. Peat-tar often contains a large percentage, but the resulting paraffin is very soft. Ozokerite and neft-oil, derived from the Caspian Sea and Hungary, now command high prices as sources of paraffin scales. Neft-oil is said to give 68 per cent. of distillate, consisting of 60 per cent. of crude paraffin and 8 per cent. of oil. The Galician ozokerite gives by distillation some 24 per cent. of paraffin, and 45 per cent. of oil.

The refining of the liquid portion of the crude oils is still conducted in the manner described. (See SHALE and MINERAL OILS.) A great many patents have been secured, a large proportion of them evidently based upon the theory that the refining of these oils is simply a process of oxidation analogous to that of the bleaching of vegetable colours. Some degree of oxidation undoubtedly does take place in the course of the refining process, but this is far from being the whole action. The sulphuric acid appears to act chiefly as a carbonising agent, and by heterogeneous adhesion to the carbonaceous or pitchy colouring-matters which it carries down with it in the form of 'acid-tar.' The theory of the action is, however, by no means fully understood. It still offers a most interesting field for a thorough investigation.

Among the many processes patented may be named the use of hypochlorite of lime, the application of chlorine gas to the vapours of the oils, of nascent chlorine to the liquid oil by the decomposition of hydrochloric acid or chloride of sodium with black oxide of manganese, the use of bichromate of potash and other chromates, and of free chromic acid, of the permanganates, and almost every known oxidising agent.

The sulphuric-acid treatment is the only method which has been found commercially successful. The proportion of acid required depends upon the oil, and must be determined by experiment. Generally speaking, the heavier oils require more acid than the lighter; but even this rule is subject to special exceptions.

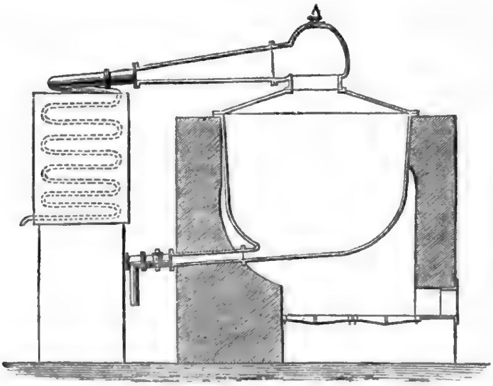
Many forms of agitators have been adopted, from simple tubs with a paddle to very complex devices worked by steam-power; the problem, however, is merely to keep a heavy liquid—sulphuric acid—stirred up amidst a lighter one—the crude, or 'once-run' oil. A *cast*-iron vessel, fitted with paddles working on an axle similar to a common churn, is the apparatus generally used. Upright cylindrical vessels, with an Archimedean screw working vertically to raise the acid from the bottom, have been used, but not extensively.

In some refineries the crude oil is treated with the acid and alkali, but more commonly it is 'once run,' as already described.

In all the stages of distillation for the refinery the use of superheated or dry steam is found very advantageous, not as the primary source of heat, but as an auxiliary. In accordance with the well-established law of diffusion of gases, the vapour from the boiling oil will diffuse much more readily into an atmosphere of steam than into one of its own vapour; and thus the superheated, or simply the dry steam, enables the distillation to be conducted at a lower temperature than would be necessary without it, which is a matter of considerable importance, not merely as regards the quantity of work done with given fuel, but also as affecting the quality of the oil produced.

The form of still most commonly used is shown in *fig.* 1610, usually of a capacity of 1,000 to 2,000 gallons. Much difference of opinion prevails among refiners as regards the merits of cast or wrought iron. Many serious conflagrations have lately occurred from the sudden cracking of cast-iron stills, which have led to a much more extensive use of wrought iron than formerly.

1610



It is a common practice in the first running of crude oil to use a wrought-iron still, or still of cast iron with bottom outlet-pipe, like that in *fig.* 1610, for the first part of the process, until the heavier products begin to run over; then to run out the residue from this still into a small round bottom still, without bottom outlet, and then 'coke down,' that is, carry on the distillation to dryness. By this means the most dangerous stage is carried on in the smaller still, which is far less liable to rupture. Wrought-iron stills cannot well be used for coking down, the great heat required destroying the rivets.

In the refining of the solid paraffin considerable progress has been made.

In the first place, the crude oil is distilled over to dryness, 'coked down,' as already described. The heavy oil obtained from the latter stages of distillation is found to contain large quantities of bright crystalline scales of solid paraffin in suspension.

Paraffin is crystallised from the first distillation in several works; but it is usually 'bagged' from the second distillation. In the crude oil, the pitchy constituents seem to cling to the paraffin particles and hold them back from crystallisation, so that they form an amorphous greasy mass when the light oil only is distilled off from the crude. This grease, however, when distilled gives over a rich lubricating oil of pale brown colour, with the paraffin crystals in such a state of free suspension that they are readily separated at a low temperature. This separation of 'brown paraffin scale' is effected by 'bagging' and pressing. The bagging is simply a filtration in canvas bags, which are usually filled and tied up, then heaped together, or thrown into perforated boxes till the greater portion of the oil filters out. The contents of the bags are then submitted to a gradually-increasing hydraulic pressure till the utmost possible degree of dryness is obtained in the cake of crystalline scales.

The quantity of solid paraffin thus obtained depends in a great measure upon the temperature at which these operations are conducted, as the oil is a solvent to the paraffin, and the quantity it is capable of dissolving rapidly increases as the temperature rises. In small works this separation of paraffin is only conducted in cool weather; in larger works, refrigerating-machines are used.

The purification of the brown paraffin scale thus obtained is now effected by the simple process of dissolving it in a hot solution of the most volatile 'paraffin spirit.'

The scale having been dissolved in about an equal weight of spirit, the solution is set to cool in suitable vessels. As it cools, the solid paraffin recrystallises, in the course of which action it rejects the impurities associated with it, giving up its brown colour and the liquid solvent. The cooled mixture of crystal and spirit is again submitted to pressure, whereby the spirit is separated, and the crystals, now of a cream colour, are again dissolved in colourless spirit, and the same treatment repeated. A third treatment is usually necessary to obtain perfect purification, when beautiful crystals of exquisite snowy whiteness are obtained, presenting the most perfect contrast imaginable to the coal from which they are derived.

The chief drawback to this process is the waste of spirit by evaporation during the cooling and pressing processes. By careful and intelligent management this waste may be materially reduced. The refuse spirit, which has received the colouring-matter and other impurities from the brown scale, is easily refined by simple distillation, and may be used again and again. The brown refuse left in the still may be treated afresh as crude paraffin scale, as there always remains a portion of paraffin in it which continued in solution when the rest crystallised out. This, however, is of inferior quality, having a lower melting-point, and is usually sold in a semi-refined state for making common candles, burning in miners' lamps, &c.

In order to remove the last traces of the spirit, which if left behind, lowers the fusing-point, besides giving its odour to the paraffin, the scales are fused and heated to about 240° Fahr.; care being taken to go no higher than this, as at 260° the paraffin acquires a yellow colour similar to that of bees'-wax. It is therefore necessary that the spirit should be freely and fully volatile at or below 240°, and that all the heavy oil should be separated in the earlier stages of the process. This fused paraffin is run into moulds, and sold in cakes as 'paraffin wax,' which is now becoming the great staple material for the manufacture of the better class of candles. Every year the price of these candles has come down lower and lower, in consequence of the increased production by improved methods.

Paraffin as washed at these various stages is now used in candle-making according to the value of the manufactured material wanted.

Whiteness, freedom from smell, and a high melting-point, are the commercial tests upon which the value of paraffin depends.

The importance of the latter may easily be understood when we consider that the melting-point of the best paraffin is but 125° Fahr., while inferior qualities are much lower. Paraffin, like wax, resin, and such substances, softens at many degrees below its melting-point; hence candles made of an inferior paraffin are liable to bend over into strange shapes in a heated ball-room, or in a hot climate. This was very vexatiously and absurdly exemplified at the coronation of the Emperor Maximilian in Mexico, when at one of the festivals all the beautiful 'spermaceti' candles, ordered expressly from England, and numbering several thousands, though brilliantly successful at first, gradually softened as the throng increased, and finally bowed over altogether, flaring hideously, and guttering in streams upon the dresses of the visitors.

Price's Candle Company, Limited, have adopted a new patented method of paraffin refining with much advantage, the cost of working being very much less, and the yield of white paraffin notably larger than formerly. As no spirits are used, a loss of about 1 cwt. of them for every ton of finished paraffin is avoided. As redistillation of the expressed oils also ceases, no loss occurs in this way of solid paraffin in solution. Much more safety also accompanies the operations of the factory. The *rationale* of the process consists in subjecting the paraffin, after being previously washed with sulphuric acid and soda, to hot pressure and *filtration* at the same time. The following details of two experiments on the commercial scale show the working of the process:—

In the first experiment, good average scale was first boiled, and blocked into a cake, which, on being cold-pressed, yielded lubricating-oil and pressed cake; which, after being again boiled and blocked, was subjected to the new method, giving a hard paraffin, which, after treatment with acid, alkali, and ivory-black, yielded finished paraffin equal to that made with the ordinary process, and having a melting-point of 129°.

There was taken of the scale 200 cwts. 1 qr. 26 lbs., which gave:—

	cwts.	qrs.	lbs.	per cent.	
Finished paraffin	131	1	27	= 65·58	
Soft paraffin, &c., of the value of ⅘ths of original scale	35	0	12	17·51	
Dark rough oil	17	2	5	8·75	
				91·84	
Loss, including paraffin left in ivory-black	16	1	10	8·16	loss.
	200	1	26	100·00	

In the second experiment, scale of a low melting-point was treated as above; only submitted twice to the special process. A paraffin with a melting-point at 130° resulted:—

Of the scale taken—69 cwts. 26 lbs.—there remained—

	cwts.	qrs.	lbs.	per cent.	
White paraffin	39	3	27	= 57·83	
Soft paraffin, &c., valued at ⅘ths of original scale	18	1	27	26·74	
Rough dark oil	6	3	0	9·76	
				94·33	
	69	0	26	5·67	loss.
				100·000	

This process must be of immense service in extracting solid paraffin for its own sake from minerals in places where mineral spirits are not a drug, as in our own mineral-oil factories.

Paraffin is mixed with 5 to 15 per cent. of stearine when moulded into candles; and to do this thoroughly well the moulds must be kept for at least an hour in a bath of hot water, at a temperature of about 190° Fahr. The mixed stearic acid facilitates the colouring of paraffin candles.

The following particulars of the paraffin trade in Scotland, derived from an authentic source, cannot be without interest:—

It is difficult to obtain statistics of the yield of burning-oil, lubricating oil, and the other products derived from shale in the process of oil-making. Naturally enough, one manufacturer does not care to let another know the particulars of his production. Hence, at best, nothing more than an estimate can be arrived at; but this coming from a source which may be relied upon, will give a tolerably fair idea of the extent of this important trade. It is estimated that not less than 800,000 tons of shale are annually put into the retorts at the various Scotch oil works. The probable yield of crude oil from this source is reckoned at 25,000,000 gallons. To obtain this result, and also for the distillation of the crude, a great amount of fuel—say 500,000 tons—must be used. The principal product from the crude is, of course, burning-oil, of which from 300,000 to 350,000 barrels may be taken as the annual yield. Some of this is sent to the Continent, but the bulk is consumed in this country. Then we have of lubricating-oil, the demand for which appears to be increasing every day, say 9,800 tons. Also paraffin wax, of which the bulk is made into beautiful semi-transparent candles, and the commonest of it is used in the manufacture of lucifer-matches, say 5,800 tons. To these figures we may add some 2,300 tons of sulphate of ammonia, and several thousand barrels of coal-oil spirit. The probable commercial value of these products cannot fall far short of a million and a quarter sterling. This valuable industry has been developed in our midst in little more than 20 years, and has had to make headway against a variety of opposing elements to its present position. The deliveries during 1872 are somewhat short of 1871 and 1870; but this is accounted for by temporary causes, such as strikes among the workmen and miners, and the high prices of coal.

PARAGUAY TEA. The leaves of the *Ilex Paraguaiensis*, which are used as tea in Brazil. They appear, like tea, to contain some *theine*, with resin, tannic acid, oil, and albumen. Paraguay tea is known also as *Maté*.

PARA NUTS. The Brazil nut, which see.

PARCHMENT. (*Parchemin*, Fr.; *Pergament*, Ger.) This writing material has been known since the earliest times, but is now made in a very superior manner to what it was anciently, as we may judge by inspection of the old vellum and parchment manuscripts. The art of making parchment consists in certain manipulations necessary to prepare the skins of animals of such thinness, flexibility, and firmness, as may be required for the different uses to which this substance is applied. Though the skins of all animals might be converted into writing materials, only those of the sheep or the she-goat are used for parchment; those of calves, kids, and dead-born lambs for vellum; those of the he-goat, she-goat, and wolves for drum-heads; and those of the ass for battledores. All these skins are prepared in the same way, with slight variations, which need no particular detail.

They are first of all prepared by the leather-dresser. After they are taken out of the lime-pit, shaved, and well washed, they must be set to dry in such a way as to prevent their puckering, and to render them easily worked. The small manufacturers make use of hoops for this purpose, but the greater employ a *herse*, or stout wooden frame. This is formed of two uprights and two cross-bars solidly joined together by tenons and mortises, so as to form a strong piece of carpentry, which is to be fixed up against a wall. These four bars are perforated all over with a series of holes, of such dimensions as to receive slightly-tapered box-wood pins, truly turned, or even iron bolts. Each of these pins is transpierced with a hole like the pin of a violin, by means of which the strings employed in stretching the skin may be tightened. Above the *herse*, a shelf is placed, for receiving the tools which the workman needs to have always at hand. In order to stretch the skin upon the frame, larger or smaller skewers are employed, according as a greater or smaller piece of it is to be laid hold of. Six holes are made in a straight line to receive the larger, and four to receive the smaller skewers or pins. These small slits are made with a tool like a carpenter's chisel, and of the exact size to admit the skewer. The string round the skewer is affixed to one of the bolts in the frame, which are turned round by means of a key, like that by which pianos and harps are tuned. The skewer is threaded through the skin in a state of tension.

Everything being thus prepared, and the skin being well softened, the workman stretches it powerfully by means of the skewers; he attaches the cords to the skewers, and fixes their ends to the iron pegs or pins. He then stretches the skin, first with his hand applied to the pins, and afterwards with the key. Great care must be taken that no wrinkles are formed. The skin is usually stretched more in length than in breadth, from the custom of the trade; though extension in breadth would be preferable, in order to reduce the thickness of the part opposite the backbone.

The workman now takes the fleshing tool represented under CURRYING. It is a semi-circular double-edged knife, made fast in a double wooden handle. Other forms of the fleshing-knife edge are also used. They are sharpened by a steel. The workman seizes the tool in his two hands, so as to place the edge perpendicularly to the skin, and pressing it carefully from above downwards, removes the fleshy excrescences, and lays them aside for making glue. He now turns round the *herse* upon the wall, in order to get access to the outside of the skin, and to scrape it with the tool inverted, so as to run no risk of cutting the epidermis. He thus removes any adhering filth, and squeezes out some water. The skin must next be ground. For this purpose it is sprinkled upon the fleshy side with sifted chalk or slaked lime, and then rubbed in all directions with a piece of pumice-stone, 4 or 5 inches in area, previously flattened upon a sandstone. The lime soon gets moist from the water contained in the skin. The pumice-stone is then rubbed over the other side of the skin, but without chalk or lime. This operation is necessary only for the best parchment or vellum. The skin is now allowed to dry upon the frame; being carefully protected from sunshine, and from frost. In the arid weather of summer, a moist cloth needs to be applied to it from time to time, to prevent its drying too suddenly; immediately after which the skewers require to be tightened.

When it is perfectly dry, the white colour is to be removed by rubbing it with the woolly side of a lambskin. But great care must be taken not to fray the surface; a circumstance of which some manufacturers are so much afraid, as not to use either chalk or lime in the polishing. Should any grease be detected upon it, it must be removed by steeping it in a lime-pit for ten days, then stretching it anew upon the *herse*, after which it is transferred to the *scraper*.

This workman employs here an edge tool of the same shape as the fleshing-knife, but larger and sharper. He mounts the skin upon a frame like the *herse* above described; but he extends it merely with cords, without skewers or pins, and supports it generally upon a piece of raw calfskin, strongly stretched. The tail of the skin being placed towards the bottom of the frame, the workman first pares off, with a sharp knife, any considerable roughnesses, and then scrapes the outside surface obliquely downwards with the proper tools, till it becomes perfectly smooth: the fleshy side needs no such operation; and indeed, were both sides scraped, the skin would be apt to become too thin, the only object of the scraper being to equalise its thickness. Whatever irregularities remain, may be removed with a piece of the finest pumice-stone, well flattened beforehand upon a fine sandstone. This process is performed by laying the rough parchment upon an oblong plank of wood, in the form of a stool; the plank being covered with a piece of soft parchment stuffed with wool, to form an elastic cushion for the grinding operation. It is merely the outside surface that requires to be pumiced. The celebrated Strasburg vellum is prepared with remarkably fine pumice-stones.

If any small holes happen to be made in the parchment, they must be neatly patched, by cutting their edges thin, and pasting on small pieces with gum-water.

Parchment is coloured green only. The following is the process. In 500 parts of rain-water, boil 8 of cream of tartar and 30 of crystallised verdigris; when this solution is cold, pour into it 4 parts of nitric acid. Moisten the parchment with a brush, and then apply the above liquid evenly over its surface. Lastly, the necessary lustre may be given with white-of-eggs, or mucilage of gum arabic.

PARCHMENT, VEGETABLE, or **PARCHMENT PAPER.** Vegetable parchment is made from unsized paper, of which ordinary blotting-paper is an example, and is well adapted for the process. This is manufactured from rags of linen and cotton, thoroughly torn to pieces in the pulping machine, and it is found that long-fibred paper is not so good for the production of vegetable parchment as that which is more thoroughly pulped. The structure of the waterleaf may be regarded as an interlacement of vegetable fibres in every direction, simply held together by contact, and consequently offering a vast extension of surface and minute cavities to favour capillary action.

To make vegetable parchment, the waterleaf or blotting-paper is dipped in diluted sulphuric acid when the change takes place, and though nothing appears to be added or subtracted, the waterleaf loses all its previous properties and becomes vegetable parchment.

This very remarkable transformation is, however, a most delicate chemical process. The strength of the acid must be regulated to the greatest nicety, for if on the one hand it is too dilute, the fibre of the paper is converted into a soluble substance, probably dextrine, and its paper-like properties are destroyed. If, however, the acid be too strong, it also destroys the paper and renders it useless.

For the most perfect result, the sulphuric acid and water should be at ordinary temperatures in the proportion of about two volumes of oil of vitriol and one volume of water, and if the paper be simply damped before immersion, the strength of the acid is altered at these spots, and the part so acted upon is destroyed.

To make vegetable parchment, the waterleaf is dipped into the sulphuric acid exactly diluted to the desired strength, when in the course of a few seconds the paper will be observed to have undergone a manifest change, by which time the transformation is effected in all its essential points. The acid has then done its work, and is to be thoroughly removed from the paper, first, by repeated washings in water, and subsequently by the use of very dilute ammonia to neutralise any faint trace of acid which escapes the washing in water. All minute traces of sulphate of ammonia left by the former process are removed as far as possible by further washings, and in certain cases the infinitesimal trace of ammonia may be removed by lime or baryta.

The action and intent of these several processes are to render the vegetable parchment perfectly free from any acid or salt, and the object is thoroughly obtained in the large way.

When the paper has undergone its metamorphosis, it is simply dried, when it becomes vegetable parchment, differing from blotting-paper, and possessing peculiarities which separate it from every other known material. The surfaces of the paper appear to have undergone a complete change of structure and composition. All the cavities of the waterleaf are closed, and the surface is solidified to such an extent, that if a portion of vegetable parchment be heated over a flame, blisters will occur from pent-up steam, which are involved in the centre of the paper, and even in the aërial state the vapour cannot pass either surface. The material of the metamorphosed surfaces is certainly one of the most unalterable and unchangeable of all known organic substances, and requires a distinctive name to indicate its individuality.

From Dr. Hofmann's report on this remarkable substance we extract the following remarks:—

'In accordance with your request, I have carefully examined the new material called vegetable parchment, or parchment-paper, which you have submitted to me for experiment; and I now beg to communicate to you the results at which I have arrived.

'I may here state that the article in question is by no means new to me. I became acquainted with this remarkable production very soon after Mr. W. E. Gaine had made known his results; and I have now specimens before me which came into my possession as early as 1854.

'The substance submitted to me for examination exhibits in most of its properties so close an analogy with animal membrane, that the name adopted for the new material seems fully justified. In its appearance, vegetable parchment greatly resembles animal parchment: the same peculiar tint, the same degree of translucency, the same transition from the fibrous to the horn-like condition. Vegetable, like animal, parchment possesses a high degree of cohesion, bearing frequently-repeated bending and rebending, without showing any tendency to break in the folds; like the latter it is highly hygroscopic, acquiring by the absorption of moisture increased flexibility and toughness. Immersed in water, vegetable parchment exhibits all the characters of animal membrane, becoming soft and slippery by the action of water, without, however, losing in any way its strength. Water does not percolate through vegetable parchment, although it slowly traverses this substance like animal membrane by endosmotic action.

'In converting unsized paper into vegetable parchment, or parchment-paper, by the process recommended by Mr. Gaine—viz. by immersion for a few seconds in oil of vitriol diluted with half its volume of water—I was struck by the observation how narrow are the limits of dilution between which the experiment is attended with success. By using an acid containing a trifle more of water than the proportion indicated, the resulting parchment is exceedingly imperfect; whilst too concentrated an acid either dissolves or chars the paper. Time, also, and temperature are very important elements in the successful execution of the process. If the acid-bath be only slightly warmer than the common temperature, 60° Fahr. (15·5° Cent.)—such as may happen when the mixture of acid and water has not been allowed sufficiently to cool—the effect is very considerably modified. Nor do the relations usually observed between time, temperature, and concentration, appear to obtain with reference to this process; for an acid of inferior strength, when heated above the common temperature, or allowed to act for a longer time, entirely fails to produce the desired result. Altogether, the transformation of ordinary paper into vegetable parchment is an operation of considerable delicacy, requiring a great deal of practice; in fact, it was not until repeated failures had pointed out to me the several conditions involved in this reaction, that I succeeded in producing papers in any way similar to those which you have submitted to me for experiment.

'It is obvious that the transformation, under the influence of sulphuric acid, of paper into vegetable parchment, is altogether different from the changes which vegetable fibre suffers by the action of nitric acid; the cellulose receiving, during its transition into *pyroxylin* and *gun-cotton*, the elements of hyponitric acid in exchange for hydrogen, whereby its weight is raised, in some cases by 40, in others by as much as 60 per cent. As the nitro-compounds thus produced differ so essentially in composition from the original cellulose, we are not surprised to find them also endowed with properties altogether different; such as increased combustibility, change of electrical condition, altered deportment with solvents, &c., whilst vegetable parchment, being the result of a molecular transposition only, in which the paper has lost nothing and gained nothing, retains all the leading characters of vegetable fibre, exhibiting only certain modifications which confer additional value upon the original substance.

'The nature of the reaction which gives rise to the formation of vegetable parchment having been satisfactorily established, it became a matter of importance to ascertain whether the processes used for the mechanical removal of sulphuric acid from the paper had been sufficient to produce the desired effect. It is obvious that the valuable properties acquired by paper, by its conversion into vegetable parchment, can be permanently secured only by the entire absence or perfect neutralisation of the agent which produced them. The presence of even traces of *free* sulphuric acid in the paper would rapidly loosen its texture, the paper would gradually fall to pieces, and one of the most important applications which suggest themselves, viz. the use of vegetable parchment in the place of animal parchment for legal documents, would thus at once be lost. The paper was found to be entirely free from this acid.

'The absence of free sulphuric acid in the parchment-paper was, moreover, established by direct experiment. The most delicate test-papers, left for hours in contact with moistened vegetable parchment, did not exhibit the slightest change of colour.'

PARIAN. See POTTERY.

PARIS BLUE. A bright blue obtained by heating aniline with chloride of tin. See ANILINE.

PARIS RED. A fine iron rouge employed for polishing.

PARKSINE. A preparation so called from the inventor, Mr. Parks of Birmingham, was exhibited at the International Exhibition of 1862. It was made by incorporating castor oil, collodion (gun-cotton dissolved in ether), and wood-spirit. The mixture gradually solidifies, and eventually becomes a hard mass. While in the pasty condition it was moulded into a great variety of forms. It has not, however, taken its place as a manufacture. See OXIDISED OILS.

PARQUETRY, *Parquetage.* Inlaid flooring. In most cases thin veneers are cut into geometric forms, and cemented to the planks which are to form the floors. Lately the Messrs. Arrowsmith have introduced their 'solid parquetry,' in which the wood is cut of the required thickness, and ingeniously joined together in geometric patterns. See BUHL; MARQUETRY; REISNER.

PARTING. See GOLD and SILVER, REFINING of.

PARTRIDGE-WOOD. The wood of several trees appears to be imported under this name. It is principally used for walking-canes, and for umbrella- and parasol-sticks.

PARVOLINE. A volatile nitryle base found in the naphtha from the Dorset Shale. It is isomeric with cumidine. It is the highest known member of the pyridine series.

PASTEL is the French name of coloured crayons. Also a dye-stuff, allied to INDIGO.

PASTES, or *Factitious Gems.* (*Pierres précieuses artificielles,* Fr.; *Glaspasten,* Ger.) See GEMS, ARTIFICIAL.

PASTILLE is the English name of small cones made of gum-benzoin, with powder of cinnamon and other aromatics, which are burned as incense, to diffuse a grateful odour, and conceal unpleasant smells in apartments. Pastille is the French name of certain aromatic sugared confections; called also *tablettes.* See PERFUMERY.

PATCHOULY. *Pachupat* or *Patscha-pat.* The herb, *Pogostemon Patchouli,* which is, on account of its pungent odour, used in perfumery. It is a herb-like plant, growing very much like sage, indigenous to Northern India; it is also found in China.

The plant grows readily in the hothouses in England; specimens are to be found at Kew and other gardens. The leaves have long been in use as a perfume, and preventive of moth. India-shawls used to be packed with patchouly, on account of its being inimical to vermin, and so efficacious in preserving them during a long voyage; it was thus patchouly was first introduced into Europe.

When the patchouly-plant is distilled it yields a dense essential oil, to which it owes its odour; this dissolved in alcohol, in the proportion of 2 ounces to 1 gallon of spirit, forms the 'essence of patchouly' of the shops. The essential oil of patchouly is one of the least volatile of any known; hence it is one of the most persistent of perfumes from plants. Under the ordinary conditions, the essential oil of patchouly is a fluid, and will not congeal, except by an excessively low temperature; but if the plant be distilled after it has been gathered several years, more than half the product will assume a crystallisable form, far less fragrant than the newer fluid essential oil, and would probably be quite odourless if repeatedly crystallised from alcohol.

The crystals of patchouly are rhombic-formed, with pyramidal summits; chemically they resemble camphor in composition. When the fluid essential oil of patchouly is submitted to fractional distillation, there comes at the highest temperature a peculiar blue body, termed by Piesse *azulene,* resembling the blue in the essential oil of wild camomile; it requires, however, further examination. See PERFUMERY.

PATENT YELLOW. An oxychloride of lead; called also Turner's Yellow and Montpelier Yellow. See CASSELL YELLOW.

PATINA. The green coating—carbonate of oxide of copper—which covers ancient bronzes and copper medals. True patina is an *ærugo,* or verdigris, produced by the long-continued action of carbonic acid on the metal buried in the soil. It is very commonly imitated by fraudulent dealers. *Patina*, or *Patella*, was also the name of a bowl made of either metal or earthenware.—*Fairholt.*

PAUL VERONESE GREEN. An artist's colour; a peculiarly-prepared carbonate of copper.

PEACH. A Cornish *miner's term*, given to chlorite and chloritic rocks. A *peachy lode* is a mineral vein containing this substance, generally of a bluish-green colour, and rather soft. See CHLORITE.

PEACH-WOOD, or *Nicaragua*, and sometimes termed *Saint Martha Wood*, is inferior to the other two named; but is much used in the dyehouse, and, for many shades of red, is preferred, although the colouring-matter is not so great. It gives a bright dye. The means of testing the quality of these woods by the dyer is similar to that described for logwood, with the same recommendations and precautions.—*Napier on Dyeing.*

PEACOCK-COPPER ORE. An iridescent copper pyrites, produced by a partial decomposition of the yellow ore. The boys and girls employed in the mines produce this condition artificially by putting the ordinary copper pyrites into warm water holding sulphate of copper in solution; and sell the beautifully-coloured specimens to strangers. A more effective way of producing this peacock copper is to take a lump of yellow copper-ore (*copper pyrites*), and, having bound a piece of copper wire around it, to connect the other end of the wire with a plate of copper. If this arrangement be made in a vessel divided by a porous partition, having a solution of sulphate of copper on the side in which the copper ore is placed, and salt and water on the other side, the change goes on rapidly, and the result is exceedingly permanent.

PEARLASH. Commercial carbonate of potash. See POTASH.

PEARL BARLEY. See BARLEY.

PEARLS (*Perles*, Fr.; *Perlen*, Ger.) are the productions of certain shellfish, such as the pearl-oyster. These mollusca are subject to a kind of disease caused by the introduction of foreign bodies within their shells. In this case their pearly secretion, instead of being spread in layers upon the inside of their habitation, is accumulated round these particles in concentric layers. Pearl consists of carbonate of lime, interstratified with animal membrane.

The oysters whose shells are richest in mother-of-pearl are most productive of these highly-prized spherical concretions. The most valuable pearl-fisheries are on the coast of Ceylon, and at Olmutz in the Persian Gulf; and their finest specimens are more highly prized in the East than diamonds, but in Europe they are liable to be rated very differently, according to the caprice of fashion. When the pearls are large, truly spherical, reflecting and decomposing the light with vivacity, they are much admired. But one of the causes which renders their value fluctuating, is the occasional loss of their peculiar lustre, without our being able to assign a satisfactory reason for it.

The following letter on the Ceylon pearl-fishery, recently written by E. W. H. Holdsworth, is of interest:—

'Skates are no new enemy to the pearl-oyster. It is an old idea among the divers that the several failures of the fishery have been due to the depredations of these fishes, and the subject was one of those to which my attention was specially directed when I was sent out by the Government in 1865 to enquire into the causes of the failure in the previous year. Skates naturally feed on shell-fish, and they are provided with teeth which enable them easily to crush the pearl-oyster, many of the broken pieces of shell being rejected, while other parts are swallowed with the oyster itself. But skates have no means of extracting the fish and leaving the shells uninjured. In 1864, when the Ceylon Government expected to obtain from the pearl-banks a revenue of 50,000*l.*, the principal bed was found covered with empty shells, a large portion of them with the valves united at the hinge, and otherwise uninjured. This was precisely the appearance which the oysters would have presented had they died a natural death, as I pointed out in my official reports. There were a few living oysters, and, in addition, a considerable number of broken shells. These last were doubtless the work of the skates.

Pearl-oysters attain their full superficial growth in about four years, but the shell thickens for two years more, and it is during this period the pearls rapidly increase in size. After about six years, the animal dies, the shell opens, and the contents disappear. It is, of course, desirable to leave the oysters on the banks as long as possible in order to obtain large pearls, but there is the danger of leaving them too long and losing them altogether. That is what occurred in 1864. I obtained ample evidence to satisfy me that the oysters should have been fished in 1863, for, according to official reports, they were beginning to die off in February of that year, and then there was no especial fear of skates. These fishes, however, were abundant in the following year; but, as I have said, there was the strongest evidence in the unbroken shells that most of the oysters had died a natural death.

'The banks, or beds, as they might more properly be called, are in from 7 to 9 fathoms water, and almost out of sight of land. They are exposed during great part of the year to strong and often irregular currents, which sweep the bottom, and from which no protection can be given; and the weather is generally so bad that a regular inspection of the banks of a fishery can only be carried on during the month of March. Skates are indigenous to the Ceylon seas, and they obviously cannot be kept away from the banks if they choose to go there; but I heard nothing after the inspection in March last of the army of monsters your correspondent speaks of: and I can only conclude that a short examination was made at the end of October, of which I have yet had no account. I hope, for the sake of the colony, that matters are not so bad as stated, for skates are undoubtedly capable of doing a vast deal of mischief, even if they do not devour all the oysters.'

Pearls of considerable beauty are found in Scotland. Mr. Alexander M. Cockburn thus describes them:—

'The beauty of lustre and form, and the fine opaque colour of the Scottish pearl, attract more attention now than formerly. The late Prince Consort ordered a necklace to be made of pearls of a certain size, which took more than twenty years to complete.

'The fishing for these pearls is now a regular trade. Fine and large specimens of pearls are found in the rivers Teith, Forth, Dee, Don, Earn, Tay, Tweed, and the rivers of Ross and Sutherlandshires. Country people often bring these treasures to town, and sell them for prices varying from a few shillings up to 25*l.* Scottish pearls are easily known from the fine Oriental pearls: they are of a different shade of colour. Pearls about the size of a pea bring as much as 15*l.* to 25*l.*; very large and fine ones from 30*l.* to 90*l.* The trade in these has increased very much within the last few years. A very fine specimen of Scottish pearl, mounted in gold, was sent from Edinburgh to the late Dublin Exhibition, the value of which was 500*l.*; it was set in enamel and gold as a tiara for a lady's head-dress.'

PEARLS, ARTIFICIAL. These are small globules, or pear-shaped spheroids of thin glass, perforated with two opposite holes, through which they are strung, and mounted into necklaces, &c., like real pearl ornaments. They must not only be white and brilliant, but exhibit the iridescent reflections of mother-of-pearl. The liquor employed to imitate the pearly lustre is called the *essence of the East* (*essence d'orient*), which is prepared by throwing into water of ammonia the brilliant scales, or rather the *lamellæ*, separated by washing and friction, of the scales of a small river-fish, the bleak, called in French *ablette.* These scales, digested in ammonia, having acquired a degree of softness and flexibility which allow of their application to the inner surface of the glass globules, they are introduced by suction of the liquor containing them in suspension. The ammonia is volatilised in the act of drying the globules. See Beckmann's 'History of Inventions' for an interesting account of this manufacture.

It is said that some manufacturers employ ammonia merely to prevent the alteration of the scales; that when they wish to make use of them, they suspend them in a well-clarified solution of isinglass, then pour a drop of the mixture into each bead, and spread it round the inner surface. It is doubtful whether by this method the same lustre and play of colours can be obtained as by the former. It seems, moreover, to be of importance for the success of the imitation that the globules be formed of a bluish, opalescent, very thin glass, containing but little potash and oxide of lead. In every manufactory of artificial pearls there must be some workmen possessed of great experience and dexterity. The French greatly excel in this ingenious branch of industry.

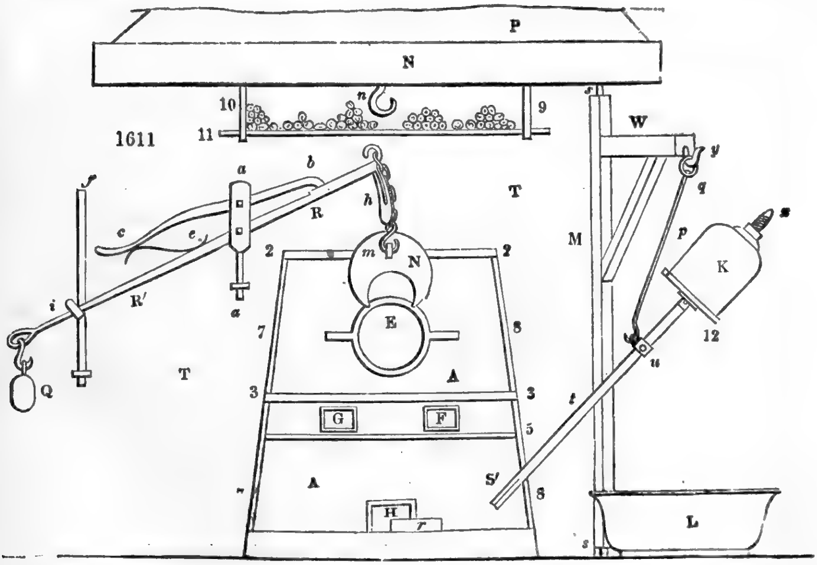
These false pearls were invented, in the time of Catherine de Medicis, by a person of the name of Jacquin. The manufacture of pearls is principally carried on in the department of the Seine in France. There are also manufactories in Germany and Italy, but to a small extent. In Germany, or rather Saxony, a cheap but inferior quality is manufactured. The globe of glass forming the pearl in inferior ones, being very thin, and coated with wax, they break on the slightest pressure. They are known by the name of German fish-pearls. Italy also manufactures pearls by a method borrowed from the Chinese: they are known under the name of Roman pearls, and are a very good imitation of natural ones; they have on their outside a coating of the nacreous liquid. The Chinese pearls are made of a kind of gum, and are covered likewise with the same liquid.

In the year 1834 a French artisan discovered an opaline glass of a nacreous or pearly colour, very heavy and fusible, which gave to the beads the different weights and varied forms found amongst real pearls. Gum, instead of wax, is now used to fill them, by which they attain a high degree of transparency, and the glassy appearance has been lately obviated by the use of the vapour of hydrofluoric acid. This acts in such a manner as to deaden the surface, and remove its otherwise glaring look.

The material out of which these beads are formed is small glass tubing, like that with which thermometers are made. The tubes for the bright-red pearls consist of two layers of glass, a white opaque one internally, and a red one externally; drawn from a ball of white enamel, coated in the Bohemian method with ruby-coloured glass, either by dipping the white ball into a pot of red glass, and thus coating it, or by introducing the ball of the former into a cylinder of the latter glass, and then cementing them so soundly together as to prevent their separation in the subsequent pearl processes. These tubes are drawn, in a gallery of the glasshouse, to 100 paces in length, and cut into pieces about a foot long. These are afterwards subdivided into cylindric portions, of equal length and diameter, preparatory to giving them the spheroidal form. From 60 to 80 together are laid horizontally in a row upon a sharp edge, and then cut quickly and dexterously at once by drawing a knife over them. The broken fragments are separated from the regular pieces by a sieve. These cylinder portions are rounded into the pearl shape by softening them by a suitable heat, and stirring them all the time. To prevent them from sticking together, a mixture of gypsum and plumbago, or of ground clay and charcoal, is thrown in among them.

Figs. 1611 and 1612 represent an apparatus for rounding the beads: *fig.* 1611 is a front view of the whole; *fig.* 1612 is a section through the middle of the former figure, in the course of its operation. The brick furnace, strengthened with iron bands, 2, 3, 5, 7, 8, has in its interior (see *fig.* 1612) a nearly egg-shaped space, B, provided with the following openings: beneath is the fire-hearth, C, with a round mouth, and opposite are the smoke flue and chimney, D; in the slanting front of the furnace is a large opening, E, *fig.* 1611. Beneath are two smaller oblong rectangular orifices, F, G, which extend somewhat obliquely into the laboratory, B. H serves for introducing the wood into the fireplace. All these four openings are, as shown in *fig.* 1612, secured from injury by iron mouth-pieces. The wood is burned upon an iron or clay bottom piece, *r*. A semi-circular cover, N, closes during the operation, the large opening E, which at other times remains open. By means of a hook, *m*, and a chain, which rests upon a hollow arch, *h*, the cover N is connected with the front end of the long iron lever R, R′. A prop supports at once the turning axis of this lever and the catch *b*, *c*; the weight Q draws the arm R down, and thereby holds up N: E therefore remains open. By rods on the back wall, T T, the hook *i*, in

1611

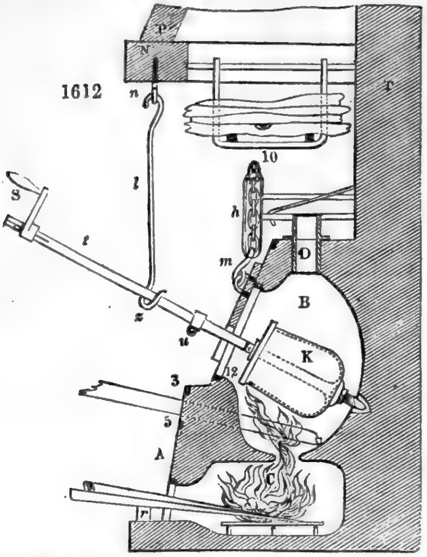


which R′ rests, proceeds from *f*. When R′ is raised, R sinks. The catch, *c b*, enters with its front tooth into a slanting notch upon the upper edge of R, spontaneously by the action of the spring *e*, whereby the opening, E, is shut.

The small door, N, rises again with the front arm of the lever by the operation of the weight Q, of itself, as soon as the catch is released by pressure upon *c*.

The most important part of the whole apparatus is the drum, K, for the reception and rounding of the bits of glass. It may be made of strong copper, or of hammered or cast iron, quite open above, and pierced at the bottom with a square hole, into which the lower end of the long rod, *t*, is exactly fitted, and secured in its place by a screwed collector nut. The blunt point *x* (*fig.* 1611) rests during the working in a conical iron step of the laboratory, *fig.* 1612. On the mouth of the drum, K, a strong iron ring is fixed, having a bar across its diameter, with a square hole in its middle point, fitted and secured by a pin to the rod *t*, and turned by its rotation. The vessel K, and its axle *t*, are laid in a slanting direction; the axle rests in the upper ring *z*, at the lower end of the rod *l*, of which the other end is hung to the hook *n*, upon the mantel-beam, N. On the upper end of *t*, the handle, S, is fixed for turning round continuously the vessel K while the fire is burning in the furnace, the fuel being put not only in its bottom chamber, but also into the holes F, G (*fig.* 1611). The firewood is made very dry before being used, by piling it in logs upon the iron bars 9, 10, 11, under the mantel-piece, as shown in *figs.* 1611, 1612.

1612



After the operation is finished, and the cover N is removed, the drum is emptied of its contents, as follows:—Upon the axle *t*, there is, towards K, a projection at *u*. Alongside the furnace (*fig.* 1611) there is a crane, M, that turns upon the step, *s*, on the ground. The upper pivot turns in a hole of the mantel-beam, N. Upon the horizontal arm, W, of the crane there is a hook, *y*, and a ring, *q*, in which the iron rod *p* is moveable in all directions. When the drum is to be removed from the furnace, the crane, with its arm W, must be turned inwards; the under hook of the rod *p* is to be hung in the projecting piece *u*, and the rod *l* is lifted entirely out. After this, by means of the crane, the drum can be drawn, with its rod *t*, out of the furnace; and, through the mobility of the crane and its parts *p*, *q*, any desired position can be given to the drum. *Fig.* 1611 shows how the workman can with his hand applied to S′ depress the axle *t*, and thereby raise the drum, K, so high that it will empty itself into the pot L, placed beneath. When left to itself, the drum on the contrary hangs nearly upright upon the crane by means of the rod *p*, and may therefore be easily filled again in this position. The manner of bringing it into the proper position in the furnace, by means of the crane and the rod *l*, is obvious from *fig.* 1612.

The now well-rounded beads are separated from the pulverulent substance with which they were mixed by careful agitation in sieves; and they are polished and finally cleaned by agitation in canvas bags. See ABLETTE.

PEARL BUTTONS. Pearl-button making is thus practised: the blanks are cut out of the shell by means of a small revolving steel tube, the edge of which is toothed as a saw, after which they are flattened or reduced in thickness by splitting, which is aided by the laminar structure of the shell. At this stage, being held in a spring chuck, they are finished on both sides by means of a small tool: the drilling is effected by the revolution of a sharp steel instrument, which acts with great rapidity. Ornamental cuttings are produced by means of small revolving cutters, and the final brilliant polish is given by the friction of rotten-stone and soft soap upon a revolving bench.

PEARL SPAR. A name commonly applied to crystallised dolomite exhibiting curved faces.

PEARL WHITE or **PEARL POWDER** is a sub-nitrate of bismuth. See Bismuth.

PEAT AND TURF. Accumulations of vegetable matter may be chiefly composed either of succulent vegetation, grasses, or marsh plants, or of trees; and the structure and condition of woody fibre is well known to be very different from that of grasses and succulent plants. There are thus two very distinct kinds of material preserved, the one undergoing change much less rapidly than the other, and perhaps much less completely. It is easily proved that from the accumulation of forest trees has been obtained the imperfect coal called *lignite*, while from marsh plants and grasses, mixed occasionally with wood, we obtain *peat*, *turf*, and *bog*. All these substances consist to a great extent of carbon, the proportions amounting to from 50 to 60 per cent., and being generally greater in lignite than in turf. On the other hand, the proportion of oxygen gas is generally very much greater in turf than in lignite. The proportion of ash is too variable to be worth recording, but is generally sufficiently large to injure the quality of the fuel.

As a very large quantity of turf exists in Ireland, covering, indeed, as much as one seventh part of the island, the usual and important practical condition of this substance can be best illustrated by a reference to that country. This will be understood by the following account of its origin, abstracted from the 'Bog Report' of Mr. Nimmo. He says, referring to cases where clay spread over gravel has produced a kind of puddle preventing the escape of waters of floods or springs, and when muddy pools have thus been formed, that aquatic plants have gradually crept in from the borders of the pool towards their deep centre. Mud accumulated round their roots and stalks, and a spongy semi-fluid was thus formed, well fitted for the growth of moss, which now especially appeared; *Sphagnum* began to luxuriate; this absorbing a large quantity of water, and continuing to shoot out new plants above, while the old were decaying, rotting and compressing into a solid substance below, gradually replaced the water by a mass of vegetable matter. In this manner the marsh might be filled up while the central or moister portion, continuing to excite a more rapid growth of the moss, it would be gradually raised above the edges, until the whole surface had attained an elevation sufficient to discharge the surface-water by existing channels of drainage, and calculated by its slope to facilitate their passage, when a limit would be, in some degree, set to its further increase. Springs existing under the bog, or in its immediate vicinity, might indeed still favour its growth, though in a decreasing ratio: and here, if the water proceeding from them were so obstructed as to accumulate at its base, and to keep it in a rotten fluid state, the surface of the bog might be ultimately so raised, and its continuity below so totally destroyed, as to cause it to flow over the retaining obstacle and flood the adjacent country. In mountain districts the progress of the phenomenon is similar. Pools, indeed, cannot in so many instances be formed, the steep slopes facilitating drainage, but the clouds and mists resting on the summits and sides of mountains, amply supply their surface with moisture, which comes, too, in the most favourable form for vegetation, not in a sudden torrent, but unceasingly and gently, drop by drop. The extent of such bogs is also affected by the nature of the rocks below them. On quartz they are shallow and small; on any rock yielding by its decomposition a clayey coating they are considerable; the thickness of the bog, for example, in Knocklaid in the county of Antrim (which is 168 feet high), being nearly 12 feet. The summit-bogs of high mountains are distinguishable from those of lower levels by the total absence of large trees.

As turf includes a mass of plants in different stages of decomposition, its aspect and constitution vary very much. Near the surface it is light coloured, spongy, and contains the vegetable-matter but little altered; deeper, it is brown, denser, and more decomposed; and, finally, at the base of the greater bogs, some of which present a depth of 40 feet, the mass of turf assumes the black colour, and nearly the density, of coal, to which also it approximates very much in chemical composition. The amount of ash contained in turf is also variable, and appears to increase in proportion as we descend. Thus, in the section of a bog, 40 feet deep, at Tunahoe, those portions near the surface contained 1½ per cent. of ashes, the centre portions 3¼ per cent., whilst the lowest four feet of turf contained 19 per cent. of ashes. In the superficial layers it may also be remarked, that the composition is nearly the same as that of wood, the succulent material being lost; and in the lower we find the change still more complete. Notwithstanding these extreme variations, we may yet establish the ordinary constitution of turf, and with certainty enough for practical use; and, on the average specimens of turf selected from various localities, the following results have been obtained:—

The calorific power of dry turf is about half that of coal; it yields, when ignited with oxide of lead, about 14 times its weight of lead. This power is, however, immensely diminished in ordinary use by the water which is allowed to remain in its texture, and which the spongy character of its mass renders it very difficult to get rid of. There is nothing which requires more attention than the collection and preparation of turf; indeed, for practical purposes, this valuable fuel is absolutely spoiled as it is now prepared in Ireland. It is cut in a wet season of the year; whilst drying, it is exposed to the weather: it hence in reality is not dried at all. It is very usual to find the turf of commerce containing one-fourth of its weight of water, although it then feels dry to the hand. But let us examine what affects the calorific power. 1 lb. of pure dry turf will evaporate 6 lbs. of water; now, in 1 lb. of turf as usually found there are ¾ lb. of dry turf, and ¼ lb. of water. The ¾ lb. can only evaporate 4½ lbs. of water; but out of this it must first evaporate the ¼ lb. contained in its mass, and hence the water boiled away by such turf is reduced to 4¼ lbs. The loss is here 30 per cent., a proportion which makes all the difference between a good fuel and one almost unfit for use. When turf is dried in the air under cover it still retains one-tenth of its weight of water, which reduces its calorific power 12 per cent., 1 lb. of such turf evaporating 5⅓ lbs. of water. This effect is sufficient, however, for the great majority of objects; the further desiccation is too expensive and too troublesome to be used, except in special cases.

The characteristic fault of turf as a fuel is its want of density, which renders it difficult to concentrate, within a limited space, the quantity of heat necessary for many operations. The manner of heating turf is, indeed, just the opposite to anthracite. The turf yields a vast body of volatile inflammable ingredients, which pass into the flues and chimney, and thus distribute the heat of combustion over a great space, whilst in no one point is the heat intense. Hence, for all flaming fires turf is applicable; there is, however, as some experiments made on Dartmoor show, some liability to that burning away of the metal which may arise from the local intensity of coke. If it be required, it is quite possible to obtain a very intense heat with turf.

The removal of the porosity and elasticity of turf, so that it may assume the solidity of coal, has been the object of many who have proposed mechanical and other processes for the purpose. It has been found that the elasticity of the turf-fibre presents great obstacles to compression, and the black turf, which is not fibrous, is of itself sufficiently dense.

Not merely may we utilise turf in its natural condition, or compressed or impregnated with pitchy matter, but we may carbonise it, as we do wood, and prepare turf-charcoal, the properties of which it is important to establish:—

By heating turf in closed vessels loss is avoided, but this process is expensive, and there is no compensation in the distilled liquors, which do not contain acetic acid in any quantity. The tar is often small in proportion; hence the charcoal is the only valuable product. Its quantity varies from 30 to 40 per cent. of dry turf. The products of the distillation of 1,157 lbs. of turf were found by Blavier to be charcoal, 474 lbs., or 41 per cent.; watery liquid, 226 lbs., or 19·3 per cent.; gaseous matter, 450 lbs., or 39 per cent.; and tar, 7 lbs., or 6 per cent.; but the proportion of tar is variable, sometimes reaching 24·5 per cent. when the turf is coked in close vessels.

The economical carbonisation of turf is best carried on in heaps, in the same manner as that of wood. The sods must be regularly arranged, and laid as close as possible; they are the better for being large, 15 inches long, by 6 broad, and 5 deep. The heaps, built hemispherically, should be smaller in size than the heaps of wood usually are. In general, 5,000 or 6,000 large sods may go to the heap, which will thus contain 1,500 cubic feet. The mass must be allowed to heap more than is necessary for wood; and the process requires to be very carefully attended to, from the extreme combustibility of the charcoal. The quantity of charcoal obtained in this mode of carbonisation is from 25 to 30 per cent. of the weight of dry turf.

For many industrial uses the charcoal so prepared is too light, as, generally speaking, it is only with fuel of considerable density that the most intense heat can be produced, but by coking compressed turf, it has already been shown that the resulting charcoal may attain a density of 1·040, which is far superior to wood-charcoal, and even equal to that of the best coke made from coal. As to calorific effects, turf-charcoal is about the same as coal-coke, and little inferior to wood-charcoal.

It is peculiarly important, in the preparation of the charcoal from the turf, that the material should be selected as free as possible from earthy impurities, for all such are concentrated in the coke, which may be thereby rendered of little comparative value. Hence, the coke from surface-turf contains less than 10 per cent. of ash, whilst that dense turf of lower strata contains from 20 to 30 per cent. This latter quantity might altogether unfit it for practical purposes.—*Ansted.*

Peat is cut and prepared in a very simple manner. The surface-matter being removed, a peculiar kind of spade, called a *slade*, is employed. This is a long spade, with a portion of the blade turned up at right angles on one side. With this the turf is cut out in the shape of thick bricks; these are piled loosely against each other to dry. The longer peat is kept, and allowed to dry, the more important it becomes as a heating agent.

On Dartmoor the peat is cut by the convicts, working in gangs; and, being dried, it is carefully stored in one of the old prisons. From this peat, by a most simple process, gas is made, with which the prisons at Prince Town are lighted. The illuminating power of this gas is very high. The charcoal left after the separation of the gas is used in the same establishment for fuel and for sanitary purposes, and the ashes eventually go to improve the cultivated lands of that bleak region. Attempts were made here many years since to distil the peat for naphtha, paraffin, &c., but the experiments not proving successful, the establishment was abandoned.

Experiments of a similar character have been made in Ireland, especially by a company working under the patents of Mr. Rees Reece. A Government Commission made their Report on these experiments. The whole matter was so ably examined by Sir Robert Kane (Director of the Museum of Irish Industry), and by his assistant, Dr. Sullivan, that we quote somewhat largely from their Report.

The object being to ascertain the necessary facts regarding the products of commercial value, the following was the course pursued:—

Specimens of turf representing the several ordinary varieties were separately experimented on, and the results examined.

The products of the distillation were collected as—1, charcoal; 2, tar; 3, watery liquids; 4, gases.

The relative quantities produced by 100 parts of peat were found to be—

	Average	Maximum	Minimum
Charcoal	29·222	39·132	18·973
Tarry products	2·787	4·417	1·462
Watery products	31·378	38·127	21·819
Gases	36·616	57·746	25·018

The peats yielding those proportions of products had been found to contain, previous to distillation, as dried in the air, a quantity of hygrometric moisture, and to yield a proportion of ashes in 100 parts, as follows:—

	Average	Maximum	Minimum
Moisture	19·71	29·56	16·39
Ashes	3·43	7·90	1·99

The several products of the distillation thus carried on were next specially examined for the several materials of which the quantities and commercial value had been the principal sources of the public interest of this inquiry.

The inquiry having reference, however, to the technical objects of the process, was carried on by examining the produce of

I. Tar, for—1, volatile oils; 2, fixed (less volatile) oils; 3, solid fats, or paraffin; 4, creosote.

II. Watery liquids, for—1, acetic acid; 2, ammonia; 3, pyroxylic spirit.

III. Gases for illuminating and heating power.

The following numbers will indicate the results obtained in average. All the details of the processes of separation, and the numbers of the individual experiments, were given in special reports.

In seven series of distillation in close vessels there was obtained from 100 parts of peat:—

	Average	Maximum	Minimum
Ammonia	0·268	0·404	0·181
or as			
Sulphate of ammonia	1·037	1·567	0·702
Acetic acid	0·191	0·286	0·076
or as			
Acetate of lime	0·280	0·419	0·111
Pyroxylic spirit	0·146	0·197	0·092
Volatile oils	0·790	1·262	0·571
Fixed oils	0·550	0·760	0·266
Paraffin	0·134	0·196	0·024

It is thus seen that the proportions of those products vary within wide limits, which are determined by differences of quality of the turf or temperature in the distillation.

Several trials were made to determine the amount of creosote present in the tar, but, although its presence could be recognised, its proportion was so minute as to render its quantitative estimation impossible. This circumstance constitutes an essential distinction between peat-tar and wood-tar, and indicates for the former an inferior commercial value, as the presence of creosote, now so extensively employed, is an element in the estimate of the price of tar obtained by distilling wood.

'It will be understood,' writes Sir Robert Kane, 'that the materials indicated in the foregoing Table by the names "fixed and volatile oils" are in reality mixtures of a variety of chemical substances of different volatilities and compositions—generally carbo-hydrogens—of which the further separation would be a labour of purely scientific curiosity, without having any bearing upon the objects of the present report. Although, therefore, those liquids were carefully examined, and observations made regarding their chemical history, I shall not embarrass the present report by reference to them in any other point of view than as products of destructive distillation, whose properties, analogous to the highly volatile and to the fixed oils repectively, may give them a commercial value such as has been represented. I may remark also, that, as a purely scientific question, the true nature of the solid fatty product is of much interest. The name paraffin has been given to this body, but in some of its characters it appears to deviate from those of the true paraffin, as described by Reichenbach to be obtained from wood-tar; those differences, however, should not contravene its commercial uses.' See PARAFFIN.

'The inquiry so far carried on sufficiently established that the peat, by destructive distillation in close vessels, yielded the several products that had been described, and were identical, or closely analogous, with those afforded in the distillation of wood or coal. The process in close retorts, however, being not at all that proposed or economically practicable for commercial purposes, it was necessary to proceed to determine whether the same varieties of peat, being distilled in a blast-furnace, with a current of air, so that the heat necessary for the distillation was produced by the combustion of the peat itself, would furnish the same products, and whether in greater or in less quantities than in the process in close vessels.

'For this purpose the cylinder, which in the former series of experiments had been set horizontally in the furnace, was placed surrounded by brickwork vertically, its mouth projecting a little at top, so that the tube for conveying away the products of the distillation passed horizontally from the top of the brickwork casing to the condensing-apparatus. Near the bottom of the cylinder the brickwork left a space where the cylinder was perforated by an aperture, 1¼ inch diameter, to which the tube of a large forge-bellows was adapted. The arrangement thus represented nearly the construction of an iron cupola. The cylinder being charged with peat, of which some fragments were first introduced lighted, and the blast being put on, the combustion spread, and the cover of the cylinder being screwed down, the distillation proceeded, the products passing with the current of air into the series of condensing-vessels, and the gases and air finally being conducted by a waste-pipe to the ash-pit of a furnace, where they were allowed to escape.

'By this means there was obtained, on a moderate scale, a satisfactory representation of the condition of air-blast distillation of peat which has been proposed as the commercial process. In so carrying it on, several interesting observations were made which will require to be noticed here in a general point of view.

'First, as to the nature and quantities of the products. The specimens of peat operated on were selected as similar to those employed in the former series of which the results have been quoted; and the products similarly treated were found to be, from 100 parts:—

	Average	Maximum	Minimum
Watery products	30·714	31·678	29·818
Tarry products	2·392	2·510	2·270
Gases	62·392	65·041	59·716
Ashes	4·197	7·226	2·493

'These several products having been further examined, as in the former case, gave from 100 parts of peat;—

	Average	Maximum	Minimum
Ammonia	0·287	0·344	0·194
or as			
Sulphate of ammonia	1·110	1·330	0·745
Acetic acid	0·207	0·268	0·174
or as			
Acetate of lime	0·305	0·393	0·256
Pyroxylic spirit	0·140	0·158	0·106
Volatile oils	1·059	1·220	0·946
Paraffin	0·125	0·169	0·086

'It is now important to compare these average results with those of the former series obtained by distillation in close vessels; we obtain—

	Average produce from close distillation	Average produce by air-blast distillation
Ammonia	0·268	0·287
or as		
Sulphate of ammonia	1·037	1·110
Acetic acid	0·191	0·207
or as		
Acetate of lime	0·280	0·305
Pyroxylic spirit	0·146	0·140
Oils	1·340	1·059
Paraffin	0·134	0·125

Experiments were made, at the request of Sir Robert Kane, by Dr. Hodges, Professor of Agriculture, to determine the commercial value of the peat products.

The quantities and nature of the products, as certified by Dr. Hodges, in the one trial which he superintended, compared with the Museum average results reduced to the same standard (Dr. Hodges' acetic acid having been 25 per cent. of real) are—

	Professor Hodges.		Museum.	
	From a ton.	From 100 parts.	From a ton.	From 100 parts.
Sulphate of ammonia	$22\frac{3}{4}$ lbs.	1·000	$24\frac{8}{10}$ lbs.	1·110
Acetic acid, real hydrated	$7\frac{1}{4}$ lbs.	0·328	$4\frac{2}{3}$ lbs.	0·207
Wood-naphtha	$83\frac{1}{4}$ oz.	0·232	$50\frac{1}{5}$ oz.	0·140
Tar	$99\frac{1}{2}$ lbs.	4·440	$53\frac{3}{4}$ lbs.	2·390

It hence is evident that the quantity of ammonia obtained at Newtown Crommelin is rather under that obtained at the Museum; but the produce of acetic acid, tar, and naphtha, has been found in average decidedly inferior to that stated, although the maximum results found in particular trials have approximated closely to Dr. Hodges' numerical results. There having been, however, apparently but a single trial so accurately followed up at Newtown Crommelin, it is necessary to contrast the results of the Museum experiments more specially with the quantitative produce expected by Mr. Reece.

Mr. Reece's statement of the produce from 100 tons of peat distilled is compared with the average results of the Museum trials in the following table:—

From 100 parts of peat.	Statement in Mr. Reece's prospectus.	Average results of Museum trials by blast-process.
Sulphate of ammonia	1·000	1·110
Acetate of lime	0·700	0·305
Wood-naphtha	0·185	0·140
Paraffin	0·104	0·125
Fixed oils	0·714	1·059
Volatile oils	0·357	

At the Sews the following manufacturing results were obtained in the year 1861 2, by Dr. B. Paul, at Sir James Matheson's works, from 100 tons of peat:—

749 gallons of oil with paraffin, @ 2*s*.		£74 18 0
From which is to be deducted—		
100 tons of peat @ 2*s*.	£10 0 0	
Cost of manufacture	28 14 6	
		38 14 6
Leaving a balance of		£36 3 6

On the contrary, the manufacturing experience of Mr. Sullivan, in Ireland, were—

150 gallons of oil @ 2*s*.		£15 0 0
300 lbs. of paraffin @ 1*s*.		15 0 0
52 gallons of wood-naphtha		2 10 0
3 cwts. of sulphate of ammonia		1 16 0
		£34 6 0
From this had to be deducted—		
100 tons of peat @ 4*s*.	£20 0 0	
Cost of manufacture	14 3 4	
		34 3 4
Leaving a balance of		0 2 8

In the present state of the oil-manufacture, 1*s.* per gallon would have to be deducted from the above-estimated results for burning oil.

Dr. Reynolds, as the Chairman of a Committee of the Royal Dublin Society on the use of peat by Siemens' regenerative furnace, reports very favourably of its use in manufactories requiring high heats. Ordinary air-dried peat, containing on an average 25 per cent. of water, when used in this furnace, compares more favourably with coal than in any other known way. The general heating power of 2¼ tons of peat is about equivalent in practice to that of one ton of average coal; but in the Siemens' furnace its value appears equivalent to not less than 65 per cent. of that of Staffordshire coal. Mr. Siemens also states that peat mixed with·25 per cent. of coal-dust gives a richer gas than peat alone. At Carlstadt, Munkfors, Sweden, F. Lundin has employed peat in iron-smelting containing as much as 45 per cent. of water. The resulting gas, which contains about 33 lbs. of water to 100 lbs. dry gas, is deprived of its vapour in a condensing arrangement of iron tubes, weighing 3,500 lbs., laid crosswise, and on which a jet of water plays. The heat of the gas before condensation always melts lead easily, and sometimes zinc. The results have been so satisfactory that a national testimonial has been presented to the inventor. This peat-furnace is preferred to that fed by dry wood, which only produces in the generators gas of a temperature of 1394°; whereas the gas from the first furnace is 2666°; less water is lodged in the condensers and the repairs are less. It is said one Lundin furnace costs in Sweden about 900*l.*; and it utilises 1,700 tons of ore in a year [*vide Reports of the United States' Commissioners to the Paris Universal Exposition*, 1867].

There exists already above 100 patents for making and converting raw peat into fuel for steam and domestic purposes. The favourite methods with inventors of treating the crude peat have been compression by hydraulic power, separation of the vegetable fibre from the matrix, maceration, grinding, and rapid drying by heated air. These modes of dealing with peat are all liable to failure from various causes. Generally peat will yield an average of 70 per cent. of water, and any process that aims at getting rid of the water in a rapid manner has not been found to answer. The application of a high degree of heat seems to overbake the peat and rob it of a large amount of its calorific value. The attempt to abstract the ligneous fibre from the humus of the peat is a costly experiment, to deprive the peat of its most substantial and valuable material for the purposes of fuel.

The Clayton method is simply to cut the peat into fragments in its raw and moist state, drain off as much of the water as will freely run away; then masticate the fibres and whole mass of peat together in a machine until it becomes difficult to distinguish any ligneous fibre distinct from the humus in which it is so entirely mixed. The peat when first cut is put into what they call squeezing-trucks; these trucks are perforated in the bottom and sides, and in the journey to the works a large proportion of the free water is squeezed out by the action of a screw or lever. The mastication or trituration of the peat is effected by means of a vertical shaft carrying a series of cutting-blades set round like a screw, and by means of these the peat is forced down into a long horizontally-placed cylinder. A revolving shaft, on which are a forcing screw, and a set of discs forming a dissecting double screw, passes through the centre of this cylinder, and cutting-blades of hard steel are fitted on the end of the cylinder furthest from the hopper. The peat, being forced into the horizontal cylinder by the blades and screws, is driven by every revolution of the discs against the cutters, thus effectively reducing the whole to a pulpy mass.

The pulped peat is then forced out through orifices in the end of the cylinder on to rollers which carry it to trays, where it is cut into lengths, and then taken to drying sheds, where it remains about three days; it is then dry enough to be stacked in open racks, where the final drying is completed.

The most important feature in this system is the breaking up of the cellular tissues of the peat, and thus getting rid of the fixed moisture: and the remarkable reduction in the size of the blocks of peat during the process of drying shows that this is done in the most complete manner. The condensed peat becomes very firm and solid, and the whole process does not take more than seven or eight days. Messrs. Clayton, Son, and Howlett assert that this fuel can be produced at a cost of from five to six shillings a ton.

Danchelle's peat-fuel and peat-filters for sewage were exhibited at Manchester, in 1874. The samples of manufactured peat-fuel made from the light brown moss, of Red Moss, Horwick, Lancashire, differed from other specimens of peat-fuel, in that the humus and ligneous fibre of the peat were macerated and reduced to a state of a fine chocolate-paste. The machine used to effect this consists of a long cylinder, in which works a shaft armed with proper cutters and discs, by which the crude peat is soon reduced to the consistency of pasty pulp, and issues in a long roll of any shape or diameter; this is cut into briquettes by a wired frame, and the briquettes are dried in the usual way, under a covered shed; in drying, they lose in their bulk, but they are in a fortnight converted into a good hard fine-grained fuel, and when roasted with charcoal, are about one-third their original size. The producers of the Danchelle peat-fuel also convert the peat into *sewage filters* by incorporating the peat with a mixture of clay and charring them. Experiments have been made, and are continued with these filters, in Bradford, Yorkshire, and in Paris, and the results are stated to be very satisfactory. Peat-fuels are prepared in Sutherland by charring the peat, which has been broken up by a machine, so as to leave it in a rough granular state, and afterwards worked up with crude shale-tar, and pressed into bricks by a moulding machine. The quantity of shale-tar taken up by the vegetable peat is very considerable, and gives it a thoroughly carbonised appearance.

The Peat Fuel and Charcoal Company, by similar manipulation and drying, obtain a remarkable degree of density, and produce samples which are close-grained, hard, and look like mahogany.

Mr. Joshua Kidd has succeeded in obtaining an excellent charcoal from peat, which answers admirably as a fuel, and as a deodoriser. It is also used as a filtering medium for foul water and sewage.

In France, peat-charcoal under the name of *Charbon roux*, is much used for making gunpowder. The Duke of Sutherland has made extensive experiments on the production of peat-charcoal. Thirty tons of this charcoal are produced weekly on the Duke's estates, costing 11*l.* 10*s.* 9*d.*

Eichorne's process for condensing peat, produces balls of a hard, clean, and convenient size, burning with a bright flame, and gives an excellent heat. Their calorific value is said to be, when compared with coal, as coal, 1·00, ball-peat, 1·37.

Mr. Robert Kerretitchison breaks up his peat with a machine, by means of which it parts with a great deal of its water. It is then manufactured in a masticator, and finely-broken asphalt is mixed with the mass. It is then shaped into briquettes, and dried under sheds. Its specific weight is less than most other peats, the addition of asphalt adds to its cost, but gives it greater value for furnaces and for raising steam.

There are several other patentees of processes for preparing peat, which differ from those already named only in some minor details, the final result being in all of them nearly similar.

Dutch peat is simply cut from the fens into bricks and dried in the air. They sell, where cut, at 12*s.* 10*d.* a ton, and in the towns at 18*s.* or 19*s.*

Korte turf is obtained by dredging in low lying water-covered bogs. It is dredged, well-trodden, and then cut into short bricks and dried. It is sold largely to hotels and the better class houses in Holland; at the peat bogs it is 14*s.* 1*d.* per ton, in the towns, 18*s.* 11*d.* *Derril turf* is found under the sand driven on the coast of Holland; it is very compact, but not much used.

Many of the particulars above given are obtained from a Lecture on Peat given by Mr. J. Plant, on the samples of that fuel exhibited in the Peel Park Exhibition, Manchester 1874, before the Manchester Literary and Philosophical Society.

Mr. O'Hara, in the 'Dublin Quarterly Journal of Science,' estimates the peat bogs of Ireland at 1,576,000 acres, occupying the limestone plains, and 1,255,000 acres, on the hills and mountains, making a total of 2,831,000 acres. Mr. Plant estimates the extent of peat in Great Britain at 3,500,000 acres, therefore the total in the British Isles will be about 6,000,000 acres; consequently, if 12 feet is assumed as the average thickness, each acre will yield 12,000 tons of peat, on the whole at least 72,000,000,000 tons of valuable fuel.

The following account of the peat-industry in Germany is extracted from the 'Allgemeine Deutsche Polytechnische Zeitung,' which gives a good account of what is doing in the matter abroad:—

'Herr Busch, a landed proprietor in Gross-Massow, near Lauenburg, appears to be carrying on the peat-industry on his own estate, and communicates to our contemporary that he was delegated by the "Lauenburg Branch" of the "Pomeranian Agricultural Society" to examine and report upon a new peat-press constructed by Stuetzke Bros., jun., Lauenburg, which commanded at the time considerable attention. After having seen the machine in operation, he was so well satisfied with its capabilities that he recommended to his branch society the purchase of one. He reports the machine to be exceedingly simple in construction, capable of working up all manners of peat, requiring little power and almost juvenile attendance. The price of the same, although not definitely mentioned, seems to be somewhere between 20*l.* and 25*l.* The following description is given:—

'The peat-press consists of a wooden tub, about 6ft. high, and 2ft. wide, chained upon a kind of sledge. The wooden vessel contains an upright shaft which may be set in motion by means of a horse-gear. This shaft carries on the bottom an iron disc, above it two revolutions or turns of screw-blades, and above these four similar blades each forming a quadrant, and so arranged that they form a complete revolution. Knife-like projections in the wooden vessel prevent the peat revolving with the blades and shaft; the opening for the introduction of the raw peat is at the back on top; in front is the iron delivery, which may be opened by means of a lever, and contains a wooden conical mould, through which the peat issues in four endless strings or streams on an inclined table, on which it is cut in pieces or blocks of convenient length. The whole of the parts of the machine are so constructed that repairs are reduced to the very minimum. The machine requires one horse, three adults, and three or four boys or girls, according to the size and distance of the drying ground. If the peat to be worked lies entirely under water or has otherwise been rendered very soft or wet, it must be thrown up to dry a little; in the same way it has to be wetted if too dry. As a rule, it may be operated upon just as dug from the bog after removal of the top layer, but if the quality varies much at different depths it is desirable to mix the same in digging and throwing out. Two men dig the peat and cart it to the machine, which is placed as close as possible; a third feeds the machine, taking care to keep it constantly full, in order to facilitate the even discharge of the streams of moulded peat. If the latter cannot be moved forward on the wetted table without getting crushed and squeezed, then the pulp is too wet; if it crumbles, it is too dry; if the stream be uneven or incomplete, the mould is clogged, and may be opened at once and the obstruction removed. Very little practice overcomes and entirely avoids these difficulties. A girl or a boy stands on the left-hand side—from the machine—of the table, and cuts from the stream with a sort of wooden spade 4 inches square—while holding the former with the left hand—a length of 10 inches, and removes the same to the end of the table, from whence it is loaded on a cart by one of the remaining two or three children, and wheeled to the drying ground. If there is sufficient room, the pieces are simply laid side by side in a dry atmosphere. Three days suffice to air-dry the same, and in two or three weeks they can be stowed into large heaps. The writer here repeats that peat having gone through this machine dries much more quickly and burns with greater intensity of heat; also that the lightest and poorest stuff so worked is fitted for consumption under steam-boilers. One volume of this pressed peat is equal to about two of Hanover peat, or to three of ordinary cut peat, and the intensity of heat developed stands in the same proportion.

'One horse is sufficient for ten hours' work per day, the dynamometer only showing 80 lbs. to 95 lbs. on a beam 13 feet 6 inches long, according to the size of the mould and the condition of the raw material, making two rounds per minute at thirty-seven paces each, or a total of seventy-four paces per minute, the exertions of the animal not lying so much in the intensity of the pull, but in going round in a circle, and this one can do easier than another. Next to the regular speed of the horse, the production of the machine depends on the size of the moulds used. No. 1 is 3½ inches square, and produces, in 50 minutes—during which the horse makes 118 rounds by exerting a pull of 80 lbs. on the 13 feet 6 inches beam—1,000 pieces of peat 10 inches long, containing 122,500 cubic inches = 70⅞ cubic feet of wet peat. Absolutely dry, one of these pieces weighs 1 lb. loth. = 1 lb. ½ oz., or rather more, in English. No. 2 is 3¾ inches square, delivering in one hour and five minutes, and 150 rounds of the horse, 1,000 pieces of peat 10 inches long, the dynamometer showing 85 lbs. to 88 lbs. on the same length of beam. The bulk of wet peat thus delivered is 81⅜ cubic feet, one piece weighing 1 lb. 17 loth—say 1 lb. 8½ oz., English, rather more—when absolutely dry. Mould No. 3 is 4 inches square, and delivers in 1 hour 15 minutes, 144 rounds of the horse with a pull of 92 lbs. to 95 lbs., the same number of pieces, viz., 1,000 also 10 inches long, being 101¼ cubic feet of wet peat, which weigh when quite dry 2 lbs. ½ oz. each piece. Some cut the peat only 8 inches long, others 12 inches; 10 inches is the best result of a number of trials. He uses form No. 3. His hands have to produce 7,000 pieces per day, and he pays 6 sgr. (7·2*d.*) per 1,000; for turning over or re-stacking, 0·6*d.* per 1,000 each time. He turns his peat over three times, and pays 9*d.* per 1,000 in the stack, but this extra expenditure is more than covered by the greater value of the product and the saving of carriage by reason of the reduced bulk. Peat thus prepared from the 1st to the 20th May proved excellent fuel in the writer's steam distillery.'

PECTIC ACID (*Acid pectique*, Fr.; *Gallertsäure*, Ger.), so named on account of its gelatinizing property, (from *πητύα*, *coagulum*), exists in a vast number of vegetables. The easiest way of preparing it, is to grate the roots of carrots into a pulp, to express their juice, to wash the *marc* with rain or distilled water, and to squeeze it well; 50 parts of the marc are next to be diffused through 300 of rain-water, adding by slow degrees a solution of one part of pure potash, or two of bicarbonate. This mixture is to be heated, so as to be made to boil for about a quarter of an hour, and is then to be thrown boiling-hot upon a filter-cloth. It is known to have been well enough boiled when a sample of the filtered liquor becomes gelatinous by neutralising it with an acid. This liquor contains pectate of potash, in addition to other matters extracted from the root. The pectate may be decomposed by a stronger acid, but it is better to decompose it by muriate of lime; whereby a pectate of lime, in a gelatinous form, quite insoluble in water, is obtained. This having been washed with cold water upon a cloth, is to be boiled in water containing as much muriatic acid as will saturate the lime. The pectic acid thus liberated, remains under the form of a colourless jelly, which reddens litmus-paper, and tastes sour, even after it is entirely deprived of the muriatic acid. Cold water dissolves very little of it; it is more soluble in boiling water. The solution is colourless, does not coagulate on cooling, and hardly reddens litmus-paper; but it gelatinises when alcohol, acids, alkalis, or salts are added to it. Even sugar transforms it, after some time, into a gelatinous state: a circumstance which serves to explain the preparation of apple, cherry, raspberry, gooseberry, and other jellies.

PECTIN, or vegetable jelly, is obtained by mixing alcohol with the juice of ripe currants, or any similar fruit, till a gelatinous precipitate takes place; which is to be gently squeezed in a cloth, washed with a little weak alcohol, and dried. Thus prepared, pectin is insipid, without action upon litmus; in small pieces, semi-transparent, and of a membranous aspect, like isinglass. Its mucilaginous solution in cold water is not tinged blue with iodine.

Frémy has published a very comprehensive investigation on the ripening of fruit, in which he shows that this peculiar body only exists in fruit arrived at maturity. Not a trace of pectin can be detected in the juice expressed from an unripe apple; but on boiling the juice for some seconds with the pulp, pectin immediately appears, and is indicated by the liquid becoming viscid. Frémy considers the following as the only way to procure pure pectin:—

From the juice of ripe pears, expressed in the cold, and filtered, the lime is to be separated by means of oxalic acid, and the albuminous substance by the aid of tannic acid. From this liquid pectin is now precipitated by means of alcohol; it separates in long threads, which after being washed with alcohol are to be dissolved in water, and again precipitated with alcohol. This is to be repeated three or four times, until the liquid is free from sugar and oxalic acid; hot water must be avoided in these operations.

PELLITORY OF SPAIN. *Pyrethrum officinale.* A native of the East. The root when chewed produces a hot sensation. It is used for toothache.

PELTRY. (*Pelleterie*, Fr.; *Pelzwerk*, Ger.) This term comprehends all the skins of the wild animals found in high northern latitudes, especially on the American continent. Under FUR these are described. It should be understood that when the skins are received in their unprepared state they are properly called *peltry* or *pelts*; when tawed or tanned they become *furs*. See FUR DRESSING.

PELT WOOL. Wool plucked from the pelts or skins of sheep after they are dead.

PEMMICAN. The North American Indians cut the muscular portions of meat into thin slices, having separated the fat, and dry it in the sun. This tough dry meat cannot undergo putrefaction; it is stamped closely together with a portion of fat, and preserved in buffalo- and deer-skins. This pemmican affords the largest amount of nutritive food in the least quantity of solid matter.

PENANG CANES are small palms which are brought from the island of Penang.

PENCIL BLUE. See CALICO-PRINTING.

PENCIL MANUFACTURE. (*Crayons, fabrique de*, Fr.; *Bleistifte Verfertigung*, Ger.) The word 'pencil' is used in two senses. It signifies either a small hair-brush employed by painters in oil and water-colours, or a slender cylinder of black-lead or plumbago, either naked or enclosed in a wooden case, for drawing black lines upon paper. The last sort, which is the one to be considered here, corresponds nearly to the French term crayon, though this includes also pencils made of differently-coloured earthy compositions. See CRAYON; DRAWING CHALKS.

The best black-lead pencils of this country are formed of slender parallelopipeds, cut out by a saw, from sound pieces of plumbago, especially such as have been obtained from Borrowdale, in Cumberland. (See PLUMBAGO). These parallelopipeds are generally enclosed in cases made of 'cedar wood,' though of late years they are also used alone, under the name of ever-pointed pencils, in peculiar pencil-cases, provided with an iron wire and screw, to protrude a minute portion of the plumbago beyond the tubular metallic case, in proportion as it is wanted. The wood commonly used for pencils, though called 'cedar,' is really a juniper, being usually obtained from the *Juniperus Virginiana.*

Pieces of plumbago sufficiently large to be thus employed are very rare, and the supply from the Cumberland mine can no longer be relied on. The mine has been closed for many years. In 1859 a company was formed for again working it, but failed to discover any plumbago of value. This year (1874) another attempt is being made to develope the mine. Many efforts have been made to utilise the smaller fragments of plumbago—as by grinding them, melting them with sulphur or antimony, and the like; but few of these have been attended with any success.

The late Mr. Brockedon was long occupied in seeking for some method which might enable him to employ the pure powder of black-lead without cementing it by any substance, which inevitably injures the quality. He endeavoured to render the powder coherent by submitting it to enormous pressure; but the different machines and apparatus he at first made use of for this purpose, however strongly they were made, were broken under the pressure, and his endeavours were thus unsuccessful, until the happy idea suggested itself of operating in a vacuum. But it was extremely difficult, if not impossible, to introduce under the receiver of an air-pump an apparatus for compressing the powder of graphite. Mr. Brockedon overcame this difficulty by an arrangement as simple as it is easily executed; for, after having compacted the powder by a moderate pressure, and thus reduced it to a certain size, he enclosed it in very thin paper glued over the whole surface. He then pierced it in one place with a small round hole permitting the escape of the air from within, when the block thus prepared was placed under an exhausted receiver, and the air having been removed, the orifice was closed with a little piece of paper (a small adhesive wafer was usually employed for this purpose), and in this state it was found that it might be left for twenty-four hours without injury. Being submitted to a regulated pressure once more, the different particles became agglomerated, and an artificial block of graphite (see GRAPHITE) was produced by simple pressure, as solid as the specimens obtained from the mine.

The artificial masses of plumbago thus obtained owed much of their character to the extreme fineness to which the plumbago was reduced by previous grinding under rollers. In this manner a great deal of useless plumbago is worked up into excellent black-lead pencils. The different degrees of darkness in drawing pencils should be secured by the selection of specimens of plumbago of varying degrees of density. It is, however, commonly obtained by combining, with the plumbago, sulphur, or sulphuret of antimony, and by subjecting the plumbago to the action of heat. In the commoner kinds of pencil a very heterogeneous mixture is employed; indeed, many pencils are little more than black chalks.

The pencil works at Keswick consist of a house of several stories, in the lower of which is a huge water-wheel turned by the Greta, outside being the cedar wood ready for use. The quantity of cedar consumed annually by the establishment is 4,000 cubic feet. These cedar logs are sawn into planks, and then a circular saw cuts the planks into smaller pieces, preparatory for the grooving-engine; this grooving-engine consists of two revolving saws, going at inconceivable speed; one saw cutting the slips of wood into narrow square rods, and the other making a groove along the rod and cutting to size at the same time; adjoining the grooving apparatus is a circular saw, cutting slips of cedar as covers to the grooved lengths.

The plumbago, if good, needs no refining; it is used precisely in the condition in which it leaves the mine. To ascertain its qualities each piece is scraped with the edge of a knife, besides being otherwise tested; and in proportion as there is no gritty particles in it, so is it the more valuable. Some pieces are harder, some a little darker in colour than others; and according to these peculiarities, they are employed for pencils of various hardness and shades. The whole knack of pencil-making seems to depend on the detection of these niceties in the bits of lead, and also, of course, in their honest adaptation to the varieties which are dealt out to the public. Plumbago of an impure kind is ground to powder; the grit, as far as possible, separated from it, and the cleansed material, mingled with a cohesive liquid, is dried and pressed into hard lumps for use. This process, however, is applied principally, if not exclusively, to the plumbago imported from India, and only in reference to pencils of the commonest sort. Pencils made with such stuff are valueless to artists; for independently of their want of tone, they are never altogether free from grit. The best pencil is one made from genuine Borrowdale lead, pure from the mine, and adapted by a skilful manufacturer to its assigned purpose. The mode of preparing the pieces of good plumbago for the pencil is very simple. All the bits, with their surface merely scraped, are glued to a board, in order to fix them in a position for being sawn. When so fixed they are brought under the action of a saw, which divides them into thin slices or scantlings. These slices are now handed to the fitter. This is an operative who, with a lot of grooved rods before him, sticks slices of the lead into grooves, snapping off each slice level with the surface, so as just to leave the groove properly filled. In the making of a single pencil, perhaps as many as three or four slice lengths are required; but however many, each slice is fitted exactly endlong with another, so as to leave no intervals. The rods being thus filled, are carried to the fastener-up. This person glues the cedar covers or slips over the filled rods; and having got a certain number arranged alongside of each other, he fixes them tightly together, and lays them aside to dry, When dried they are ready for being rounded. The rounding is done by an apparatus fixed to a bench, containing revolving planes or turning tools. Into this engine, rods are put one after another, and out they come as fast as the eye can follow them, rounded to a perfect nicety. By this simple and efficient machine a man will round from six hundred to eight hundred dozens of pencils in a day. After being rounded they get a smoothing with a plane, and then they are polished by being rubbed with a peculiar kind of fish-skin; this latter operation being performed by girls. Being polished, the next step is to cut the rods into lengths with a circular saw, after which the lengths are respectively smoothed at the ends. Nothing now remains but to stamp the name of the maker, with the letters significant of their quality. The stamping-engine is as ingenious a piece of machinery as is in the establishment. Fed into it, the pencils are stamped in less than an instant of time. A girl will with this apparatus stamp two hundred pencils per minute. Gathered from a box below into which the pencils fall, they are carried away to be tied in bundles.

In the year 1795 M. Conté invented an ingenious process for making artificial black-lead pencils.

Pure clay, or clay containing the smallest proportion of calcareous or siliceous matter, is the substance which he employed to give aggregation and solidity, not only to plumbago-dust, but to all sorts of coloured powders. That earth has the property of diminishing in bulk and increasing in hardness, in proportion to the degree of heat it is exposed to, and hence may be made to give every degree of solidity to crayons. The clay is prepared by diffusing it in large tubs through clear river-water, and letting the thin mixture settle for two minutes. The supernatant milky liquor is drawn off by a syphon from near the surface, so that only the finest particles of clay are transferred into the second tub, upon a lower level. The sediment, which falls very slowly in this tub, is extremely soft and plastic. The clear water being run off, the deposit is placed upon a linen filter, and allowed to dry. It is now ready for use.

The plumbago must be reduced to a fine powder in an iron mortar, then put into a crucible, and calcined at a heat approaching to whiteness. The action of the fire gives it a brilliancy and softness which it would not otherwise possess, and prevents it from being affected by the clay, which it is apt to be in its natural state. The less clay is mixed with the plumbago, and the less the mixture is calcined, the softer are the pencils made of it; the more clay is used, the harder are the pencils. Some of the best pencils made by M. Conté were formed of two parts of plumbago and three parts of clay; others of equal parts. This composition admits of indefinite variations, both as to the shade and hardness—advantages not possessed by the native mineral.

The materials having been carefully sifted, a little of the clay is to be mixed with the plumbago, and the mixture is to be triturated with water into a perfectly uniform paste. A portion of this paste may be tested by calcination. If on cutting the indurated mass particles of plumbago appear, the whole must be further levigated. The remainder of the clay is now to be introduced, and the paste is to be ground with a muller upon a porphyry slab, till it be quite homogeneous, and of the consistence of thin dough. It is now to be made into a ball, put upon a support, and placed under a bell glass inverted in a basin of water, so as to be exposed merely to the moist air.

Small grooves are to be made in a smooth board, similar to the pencil parallelopipeds, but a little longer and wider, to allow for the contraction of volume. The wood must be boiled in grease, to prevent the paste from sticking to it. The above-described paste being pressed with a spatula into these grooves, another board, also boiled in grease, is to be laid over them very closely, and secured by means of screw-clamps. As the atmospheric air can get access only to the ends of the grooves, the ends of the pencil-pieces become dry first, and by their contraction in volume get loose in the grooves, allowing the air to insinuate further, and to dry the remainder of the paste in succession. When the whole piece is dried, it becomes loose, and might be turned out of the grooves. But before this is done, the mould must be put into an oven moderately heated, in order to render the pencil-pieces still drier. The mould should now be taken out, and emptied upon a table covered with cloth. The greater part of the pieces will be entire, and only a few will have been broken if the above precautions have been duly observed. They are all, however, perfectly straight, which is a matter of the first importance.

In order to give solidity to these pencils, they must be set upright in a crucible till it is filled with them, and then surrounded with charcoal-powder, fine sand, or sifted wood-ashes. The crucible, after having a luted cover applied, is to be put into a furnace, and exposed to a degree of heat regulated by the pyrometer of Wedgwood; which degree is proportional to the intended hardness of the pencils. When they have been thus baked, the crucible is to be removed from the fire, and allowed to cool with the pencils in it.

Should the pencils be intended for drawing architectural plans, or for very fine lines, they must be immersed in melted wax or suet, nearly boiling hot, before they are put into the cedar cases. This immersion is best done by heating the pencils first upon a gridiron, and then plunging them into the melted wax or tallow. They acquire by this means a certain degree of softness, are less apt to be abraded by use, and preserve their points much better.

When these pencils are intended to draw ornamental subjects with much shading, they should not be dipped as above.

Second Process for making Artificial Pencils, somewhat differing from the preceding.—All the operations are the same, except that some lamp-black is introduced along with the plumbago-powder and the clay. In calcining these pencils in the crucible, the contact of air must be carefully excluded, to prevent the lamp-black from being burned away on the surface. An indefinite variety of pencils, of every possible black tint, may thus be produced, admirably adapted to draw from nature.

Another ingenious form of mould is the following:—

Models of the pencil-pieces must be made in iron, and stuck upright upon an iron tray, having edges raised as high as the intended length of the pencils. A metallic alloy is made of tin, lead, bismuth, and antimony, which melts at a moderate heat. This is poured into the sheet-iron tray, and, after it is cooled and concreted, it is inverted, and shaken off from the model bar, so as to form a mass of metal perforated throughout with tubular cavities, corresponding to the intended pencil-pieces. The paste is introduced by pressure into these cavities, and set aside to dry slowly. When nearly dry, the pieces get so much shrunk that they may readily be turned out of the mould upon a cloth table. They are then to be completely desiccated in the shade, afterwards in a stove-room, next in the oven, and lastly ignited in the crucible, with the precautions above described.

M. Conté recommended the hardest pencils of the architect to be made of lead melted with some antimony and a little quicksilver.

In their further researches upon this subject, M. Conté and M. Humblot found that the different degrees of hardness of crayons could not be obtained in a uniform manner by the mere mixture of plumbago and clay in determinate doses. But they discovered a remedy for this defect in the use of saline solutions, more or less concentrated into which they plunged the pencils, in order to modify their hardness and increase the uniformity of their texture. The non-deliquescent sulphates were preferred for this purpose; such as sulphate of soda, &c. Even syrup was found useful in this way.

PENS, STEEL, AND OF OTHER METALS. As peculiar elasticity is required in these pens, now so commonly used, the best metal, made from either Dannemora- or hoop-iron, is selected and laminated into slips about 3 feet long and 4 inches broad, of a thickness corresponding to the desired thickness and flexibility of the pens. These slips are subjected to the action of a stamping-press, somewhat similar to that for making buttons. (See BUTTON; PLATED WARE.) The point destined for the nib is next introduced into an appropriate gauged hole of a little machine, and pressed into the semi-cylindrical shape; where it is also pierced with the middle slit and the lateral ones, provided the latter are to be given. The pens are now cleaned, by being tossed about among each other in a tin cylinder, about 3 feet long and 9 inches in diameter, which is suspended at each end upon joints to two cranks, formed one on each of two shafts. The cylinder, by the rotation of a fly-wheel, acting upon the crank-shafts, is made to describe such revolutions as agitate the pens in all directions, and polish them by mutual attrition. In the course of four hours several thousand pens may be finished upon this machine.

When steel pens have been punched out of the softened sheet of steel by the appropriate tool, fashioned into the desired form, and hardened by ignition in an oven and sudden quenching in cold water, they are best tempered by being heated to the requisite spring-elasticity in an oil-bath. The heat of this bath is usually judged of by the appearance to the eye; but this point should be correctly determined by a thermometer, according to the scale (see STEEL); and then the pens would acquire a definite degree of flexibility or stiffness, adapted to the wants and wishes of the consumers.

The following description of the pens made at the works of the late Joseph Gillott, Birmingham, will illustrate the entire manufacture:—

The steel is procured at Sheffield; it is cut into strips, and the scales removed by immersion in pickle composed of dilute sulphuric acid. It is passed through rollers, by which it is reduced to the necessary thickness; it is then in a condition to be made into pens, and is for this purpose passed into the hands of a girl, who is seated at a press, and who, by means of a bed and a punch corresponding, speedily cuts out the blank. The next stage is, piercing the hole which terminates the slit, and removing any superfluous steel likely to interfere with the elasticity of the pen; at this stage they are annealed in quantities in a muffle, after which, by means of a small stamp, the maker's name is impressed upon them. Up to this stage the future pen is a flat piece of steel: it is then transferred to another class of workers, who, by means of the press, make it concave, if a nib; and form the barrel, if a barrel-pen. Hardening is the next process: to effect this, a number of pens are placed in a small iron box and introduced into a muffle; after they become of a uniform deep red, they are plunged into oil; the oil adhering is removed by agitation in circular tin barrels. The process of tempering succeeds; and, finally, the whole are placed in a revolving cylinder with sand, pounded crucible, or other cutting substances, which finally brightens them to the natural colour of the material. The nib is ground with great rapidity by a girl, who picks it up, places it in a pair of suitable plyers, and finishes it with a single touch on a small emery-wheel. The pen is now in a condition to receive the slit, and this is also done by means of a press. A chisel or wedge with a flat side is fixed to the bed of the press; the descending screw has a corresponding chisel cutter, which passes down with the minutest accuracy; the slit is made; and the pen is completed. The last stage is colouring brown or blue; this is done by introducing the new pens into a revolving metal cylinder, under which is a charcoal stove, and watching narrowly when the desired tint is arrived at. The brilliancy is imparted by means of lac dissolved in naphtha; the pens are immersed in this, and dried by heat. Then follow the counting and selecting. Women are mostly employed in the manufacture, with skilled workmen to repair and set the tools. In this manufactory there are employed more than 500 hands, of which four-fifths are women. The manufactory has been established upwards of 50 years, and has been the means of introducing many improvements in the manufacture.

Since steel necessarily corrodes by the constant action of the acids in the ink, it has been thought that they would be protected by coating them with gold or silver; and this has been effected by the electrotype process. In most cases, however, the thin film of gold is rapidly removed, and the protection therefore afforded is small. The manipulatory details in the manufacture of gold and silver pens are so nearly similar to those above described, that it is thought unnecessary to repeat them. The best gold pens are tipped with a native alloy, which is a compound of osmium and iridium. See Osmiridium.

The importance of this manufacture will be best shown by Mr. Samuel Timmins's account of it in 'The Resources, Products, and Industrial History of Birmingham':—

'The number of actual makers of steel pens is 12. The number of men employed, 360; the number of women and girls, 2,050. The amount of horse-power employed may be estimated at 330, including, say, 50 employed in out-work rolling. The number of pens made weekly, 98,000 gross. The quantity of steel used weekly, 9½ to 10 tons. The value of pens per gross, 1½*d.* to 1*s.*; and of barrel-pens, from 7*d.* to 12*s.* per gross; some of the larger pens being very much higher, according to their size and finish.

'The increase of men and boys from 300 to 360, of women and girls from 1,550 to 2,050, of horse-power from 228 to 330, of steel used from 6½ to 10 tons, of pens made from 65,000 to 98,000 weekly, will sufficiently indicate the rapid development of the trade during the past sixteen years. These returns of the number of persons employed, amounting to 2,400 persons, do *not* include the large number employed in making the paper boxes and other accessories of the trade; and doubtless more than 2,000 persons are more or less directly connected with the steel-pen trade in Birmingham alone.

'One point relating to the cost of pens is very remarkable—the wonderfully low rate at which they are now produced. Thirty years ago, pens were sold, wholesale, at 5*s.* a gross, and now they are sold as low as 1½*d.* and 1¾*d.* per gross! When it is remembered that each gross requires 144 pieces of steel to go through at least twelve processes, the fact that 144 pens can be sold for 1½*d.* is a singular example of the results attainable by the division of labour and mechanical skill.

'Although most of the steel used for pens is produced in Sheffield, all the subsequent processes are carried on in Birmingham, which is now the head-quarters of the steel-pen trade. Two new factories had been established in France in 1849, in consequence of the high duties on English pens; and these factories (now six or seven) produce about 50,000 gross of pens per week, against 16,000 or 18,000 gross made in 1849. In Germany there are two factories, producing, however, very few pens. In America the high war-tariff has caused the establishment of four factories; and these, aided by skilled workmen from England, are producing about 10,000 gross of pens per week.

'Most of the processes of pen-making are performed by hand-presses, to cut out the blanks, to pierce the hole, to form the nib, to emboss the pattern, and to mark the name; self-acting machinery being used only for the commonest export pens.'

PEPERINO. Volcanic tufa: a light porous species of volcanic rock, so called on account of the peppercorn-like fragments of which it is composed.

PEPPER. (*Poivre*, Fr.; *Pfeffer*, Ger.) The pepper-tree (*Piper nigrum*) is cultivated in many parts of India, and to some extent in the West Indies. When the berries begin to change colour from green to red, they are collected, spread out, and dried in the sun. The stalks are separated by hand-rubbing, and then winnowing. The dry and shrivelled berries constitute the *black pepper*; the soundest grains are selected for *white pepper*. These are soaked in water until they swell and burst their corticle, which is afterwards separated by hand-rubbing and winnowing.

In McCulloch's 'Dictionary of Commerce' is a paper on the production of pepper, by Mr. Crawford, in which we find the following distribution:—

	lbs.
Sumatra (west coast)	20,000,000
Sumatra (east coast)	8,000,000
Islands in the Straits of Malacca	3,600,000
Malay Peninsula	3,733,333
Borneo	2,666,667
Siam	8,000,000
Malabar	4,000,000
Total	50,000,000

Pereira particularises the following kinds of pepper:—

1. *Malabar Pepper.*—The most valuable; a *brownish-black*.
2. *Penang Pepper.*—*Brownish-black*; but dusty. Sometimes used in England to manufacture white pepper.
3. *Sumatra Pepper.*—This is the cheapest sort. It is the black pepper of commerce. The heavier kinds are the most esteemed, and are known as *shot pepper*.
4. *Fulton's Decorticated Pepper.*—Black pepper, deprived of its husks by mechanical trituration.
5. *Bleached Pepper.*—Penang pepper bleached by chlorine.
6. *White Pepper*, described above.
7. *Tellicherry Pepper.*
8. *Common White Pepper.*—Comes from Penang by Singapore.

Pepper is stated to be adulterated with sago. This can always be detected by the microscope, the starch grains of sago being very much larger than those of pepper. Dr. Hassall has stated in the 'Lancet' that, although he frequently found pepper to be adulterated with linseed-meal, rice, and wheat-flour, yet, that out of forty-three samples obtained from various sources, he did not detect sago-meal in any.

Four pounds of black pepper yield only about one ounce of piperine, or 1-636th part. It is an insipid crystalline substance, insoluble in water, but very soluble in boiling alcohol, and is extracted at first along with the resin, which may be separated from it afterwards by potash. See PIPERINE.

PEPPER BETEL. The *Chavica betel* and the *C. Siriboa* yield the leaf which, mixed with slices of the betel nut (*Areca catechu*), is employed for mastication by many of the nations of the East. See BETEL.

PEPPER, JAMAICA. See PIMENTO.

PEPPER, LONG. *Chavica Roxburghii* (*Piper longum*). This shrub is cultivated in Bengal, and forms a considerable article of commerce all over India. The common long pepper is of a greyish-brown; it is cylindrical, and of about an inch in length.

PEPPERMINT. The *Mentha piperita*, a labiate herb, yielding preparations having stimulant and carminative qualities, such as peppermint-water, essence of peppermint, oil of peppermint, &c.

PEPSIN. The 'active principle,' or digestive 'ferment,' of gastric juice.

A preparation is sold as pepsin for coagulating milk. It is prepared by drying the glandular layer of a calf's or pig's stomach at a low temperature. Pepsin is employed advantageously in medicine. See Watts's 'Dictionary of Chemistry.'

PERCUSSION CAPS. The universal employment of the percussion cap in the place of the flint-lock has given rise to many most extensive manufactories devoted to their construction. Thin-rolled copper, as pure as possible, is selected. This is first cut into pieces called *blanks*. These are then punched up into the required shape.

They are charged by touching the bottom of each cap with a strong adhesive liquid, and before this hardens, the fulminating composition is dropped in. All that does not adhere is shaken out. The caps are varnished, and preserved for use. See FULMINATES.

PERFUMERY, ART OF, (*Parfumerie*, Fr.; *Wohlriechende Kunst*, Ger.) consists in the extraction of the odours of plants; isolating them—A and B—and in combining them with inodorous materials, such as grease, C; spirit, D; starch, E; soaps, F: also in the manufacture of cosmetics, G; dentifrices, pastes, tinctures, H; incense and pastils, I; pomades, oil, and other toilet-appendages, K; hair-washes, hair-dyes, and depilatories, L.

(A and B.) There are three distinct methods of procuring the odours of plants: 1st. By DISTILLATION. If cloves, cinnamon-bark, or the odorous leaves of plants or wood, be distilled, the fragrant principle contained therein rises with the steam, which being condensed, the otto, or essential oil, will be found floating upon the water. This process has already been described (see DISTILLATION; REFRIGERATION; OTTOS; OILS, VOLATILE; but can only be beneficially applied by the perfumer to the procuring of certain odours: from woods, such as santal and cedar; from leaves, such as patchouli and bay leaves; from various grasses, such as the lemon grass and citronella of Ceylon; from several seeds, such as carraway and nutmeg; and but to two or three flowers, such as orange-blossom, rose, and lavender. The various fragrant woods, seeds, and leaves are, however, almost as numerous as there are plants upon the earth, and as a consequence, the perfumer can have as great a variety of ottos by distilling for them.

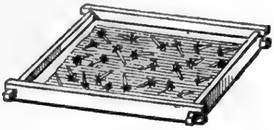
(C.) 2nd. ENFLEURAGE. When it is desired to obtain the odours of flowers, such as those of jasmin, acacia, violet, tuberose, jonquil, and numerous others, the process of distillation is inapplicable and useless, and that peculiar but simple method, termed 'Enfleurage,' must be adopted. This plan is founded on the fact, that greasy bodies readily absorb odorous particles, and will as freely part with them if in contact with pure alcohol. The operation of enfleurage is thus conducted at Messrs. Piesse and Lubin's laboratory of flowers, near Nice, in France.

Purification of the grease. A corps, or body grease, is first produced by melting together equal parts of deer- or beef-suet (the former is preferred), mutton-suet, and lard; it is then clarified thus:—Take 1 cwt. of grease, divide it into portions of about 2 lbs., place one of these in a mortar and well pound it; when it is well crushed, wash it with water repeatedly, so long, in fact, until the water is as clear, after withdrawing the grease, as before it was put in. The several lots of grease prepared in this way have now to be melted over a slow fire, adding thereto about 3 ounces of crystallised alum in powder and a handful of sea salt (common salt); now let the grease boil, but allow it to bubble for a few seconds only; then strain the grease through a fine linen into a deep pan, and allow it to stand to clear itself from impurities for about two or three hours. The clear grease is then again put into the melting vessel over a charcoal fire, adding thereto about three or four quarts of rose-water and half a pound of powdered gum benzoin; it is then allowed to boil gently, and all scum that rises carefully removed until it ceases to be produced. Finally, the grease is poured into deep pans to cool; when solid it is removed off the sedimentary water, and again being liquefied may be placed in store vessels for future use, where it may be kept for an indefinite period without change or becoming rancid. This purification of the grease gives employment to those engaged in the laboratory at a season when the flowers are not in bloom. M. Herman of Cannes, and M. Pilar of Grasse, prepare in this way during winter, together, one hundred and twenty thousand pounds of *perfectly inodorous grease.*

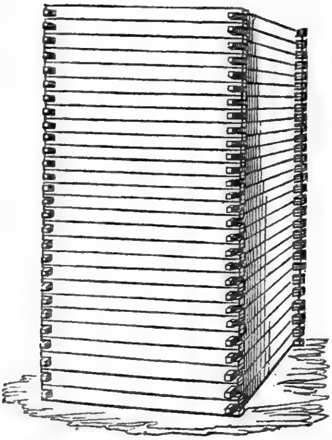
The growers of the flowers of course pay due attention to their cultivation, so as to produce an abundance of blossom in due season. Although it is not necessary that the flower-farmer should be a perfumery-factor, it is useful that the latter should have some knowledge of the former avocation, so as to be prepared for each harvest of flowers as they succeed each other, and when it is practicable to unite the occupations; better pecuniary results follow. At Cannes and Grasse, in France, which are separated from the frontier of Sardinia only by the river Var, and are distant from Nice about 30 miles, the entire population is more or less interested in this particular manufacture. The various flowers there cultivated do not come into blossom at one time, but in succession; so that there is ample time to attend to each in turn.

The enfleurage process is thus conducted:—Square frames, varying in size from 20 to 30 inches are made, in the centre of which is fixed a piece of stout glass as in *fig.* 1613. Each frame is 1½ inch deep from the top edge to the glass, so that if two frames be placed together face to face, there is, as it were, a glass box with a wooden frame, having a depth of 3 inches between each glass. This affords ample room for the blossoms to lie between them without being crushed. In due season, that is, when the flowers begin to bloom, about half a pound of the purified grease is spread upon each side of the glass with a spatula or palate-knife. The gathered blossoms are then hand-sprinkled or broad-cast over the grease in one frame, and another frame is put over it so as to enclose the flowers. This operation is repeated as many times as there are flowers to spread over each. These frames are termed *Châsse*, which literally means 'Sash.' Now we are all familiar with window-sashes—that is, a glass with a frame round it—and such is in truth the Châsse used in the enfleurage process. Doubtless our window-'sash' is derived from the French. Châsse may also be rendered in English, 'a frame.' Enfleurage, then, is conducted upon a glass frame or sash. About every other day, or every third day, the spent flowers being thrown away, fresh ones are placed upon the grease; this manipulation being repeated so long as the plants yield blossoms, a time that varies from 1 to 2 months. After every addition of flowers, it will be observed that the grease increases in the fragrance of the flower with which it was sprinkled, and this continues till the enfleurage is complete, at which time the grease, now called 'Pomade,' is scraped off the sashes, put into vessels, then placed in hot water—a water-bath. By so doing the pomade is liquefied, but is not made hot enough to destroy its odour. By this treatment various extraneous matters, such as a few anthers of flowers, a stray bee, some pistils or loose part of the corolla, a wayward butterfly and moth, and such similar things, are removed, by pouring the clear pomade into the canisters through fine linen. When the pomade is cold enough it sets in these vessels, and is then fit for exportation or for ulterior uses. *Fig.* 1614 represents a pile of châsse.

1613



1614



3. Maceration. In some few instances better results are obtained by adopting the process of maceration, which consists in infusing the fresh flowers in liquefied grease. For this purpose, the purified grease is placed in a hot water-bath, that is, the vessel containing the grease is set in another of a larger size, in which water is kept warmed over a stove. In the French laboratories, this apparatus is known as the *bain marie*, salt being put into the water to increase its boiling-point. Every time fresh flowers are gathered, the spent ones are strained away, and the fresh flowers put into the partially-scented grease. In a few instances it is found advantageous to begin perfuming the grease by maceration, and to finally finish it by enfleurage; this is especially the case with violet pomade.

After the maceration is completed, that is, when there are no more flowers to be had, the grease must be kept steadily at a uniform degree of liquefaction, in order that friable portions of the flowers, &c., may subside, so that the fair pomade can be separated therefrom pure and unsullied. Oils are scented by enfleurage and maceration processes by a slight difference of mechanical arrangement. Thus, the sash, in lieu of glass, contains a wire-gauze, like a coarse wire-blind (*châsse en fer*); upon this gauze is laid a thick piece of fustian-like cotton fabric (*molleton du coton*), which has previously been steeped in the purest olive oil. Upon each molleton laid in the sash-frame the flowers are sprinkled in the same way as if it were for pomade, and the flowers are changed as often as possible. When the plants cease to bloom, each molleton is wrapped in a strong cord net, and placed in a hydraulic or other press, for the purpose of squeezing the fragrant oil away from it. Oils of tuberose, rose, violet, jonquil, acacia, and orange are thus prepared.

According to the length of time the enfleurage process occupies, and the quantity of flowers employed over the same grease, the pomade or oil bears numbers respectively. Thus we have No. 12 pomade, No. 18 oil, No. 24 pomade, indicating their relative strength of fragrance; that is, the quantity of flowers employed in their manufacture.

(D.) Scented Spirits are produced by four separate plans:—

1. By distilling alcohol with an otto, such as lavender otto, to produce spirit of lavender. For this purpose, and to produce the finest distillate, take

Oil of English lavender	8 ounces
Rectified spirit 60° o. p.	8 pints
Rose-water	1 pint

Mix the oil first with the spirit, then gradually add the water; finally, distil off eight pints for sale. This distillate is unalterable by age, remains perfectly white, and will keep good in any climate. A great variety of scented spirits are made in this way, of which Hungary water and Eau d'Arquebuzade are good examples, the different scent or flavour being imparted by varying the combination of essential oils.

2. All essential oils being soluble in alcohol, a ready way of producing some kinds of concentrated essences is to dissolve the fragrant essential oil in the spirit. Thus, for

Essence of Roses.

Take alcohol, 60° o. p.	1 gallon.
„ pure otto of roses	3 ounces.

The oil quickly dissolves at a summer heat; but, in cold weather, beautiful acicular crystals appear throughout the liquid. Innumerable other concentrated essences may be produced in a similar way; but the standard strength varies with the oil used. Thus, for every gallon of spirit employed we should use 2 ounces of oil of vitivert, 3 ounces of oil of patchouli, 6 ounces of oil of geranium, 8 ounces of otto santal, &c.

3. Tincturation. — Musk, orris-root, ambergris, tonquin-beans, castor, vanilla, civet, and a few other odorous substances, yield their odours to spirit by tincturation, that is, by putting the fragrant material into the spirit, and allowing it to remain there for a period till the alcohol has extracted all the scent. The standard strength of these tinctures should be: for one gallon of alcohol, 2 ounces of grain musk, 3 ounces of ambergris, 8 ounces of vanilla, 8 lbs. of orris-root, 1 lb. of tonquin-beans. The standard strength of these essences is regulated, like that of 'jewellers' gold,' by the selling price; but the above is that figuratively indicated as alone worthy of the 'hall-mark.'

4. Enfleurage Essences.—The great bulk of the fine quality perfumes are procured by extracting the fragrance from the enfleurage-made pomades and oils, by contact of fine alcohol with the grease or oil. The pomade is chopped up very fine and put into the spirit, and allowed to remain together for one month at a summer heat.

Supposing the finest, or No. 24, pomade or oil is used, the standard strength of these essences should be: for one gallon spirit rectified 60° over proof, of rose pomade or oil, 8 lbs.; of acacia, 6 lbs.; of orange-flower, 8 lbs.; of jasmin, tuberose, violet, jonquil, 7 lbs.

If oils be used, the spirit and oil require to be well shaken together daily, because the oils, by their greater specific gravity, sink out of contact with the spirit. By continual agitation, the oils will not require many hours to part with their fragrance, in consequence of the mechanical subdivision which they are capable of, and hence are more intimately blended for the time with the spirit.

In this way are obtained essences of tuberose, orange-flowers, violet, jonquil, rose, acacia, and jasmin. What are called 'bouquets' and 'nosegays' are mere mixtures of the above primitive odours. A few examples we now give:—

Her Majesty's Perfume.

Enfleurage rose.	1 pint.	Enfleurage tuberose	½ pint.
„ violet	1 „	Tincture orris.	¼ „
„ orange	½ „	„ vanilla	¼ „

Albion Nosegay.

Essence of rose.	1 pint.	Tincture musk	⅛ pint.
Enfleurage rose	1 „	„ castor	⅛ „
Tincture orris.	½ „	Essence of bergamot	¾ ounce.
„ vanilla	¼ „		

White Roses.

Enfleurage rose	1 pint.	Enfleurage jasmin.	¼ pint.
Essence of rose	1 „	Essence patchouli.	⅛ „
Enfleurage acacia	½ „		

Excelsior Perfume.

Enfleurage acacia	1 pint.	Tincture vanilla	½ pint.
,, orange	1 ,,	,, civet	¼ ,,
,, jasmin	1 ,,	Oil of almonds	½ drachm.
Essence of rose	1 ,,		

Frangipanni's Scent.

Enfleurage violet	1 quart.	Tincture tonquin-beans	½ pint.
Tincture of orris	1 ,,	,, musk	¼ ,,
,, vanilla	1 pint.	Essence santal-wood	¼ ,,
Essence neroli	1 ,,	Essential oil of cloves	⅓ drachm.
,, rose	1 ,,		

St. Valentine's Nosegay.

Enfleurage acacia	1 quart.	Tincture balsam of Peru	¼ pint.
,, jasmin	1 pint.	Essence, citron zeste	1 ounce.
,, jonquil	1 ,,	,, orange zeste	½ ,,
Spirit of rose	1 ,,		

Every perfumer has some special formula, so that scarcely two houses work exactly the same mixture; although the *predominating* essences may be recognised which gives each particular perfume some speciality, as the bergamot does in the Albion nosegay, and the patchouli does in the white roses of the above.

Hungary Water and *Eau de Cologne.*

These preparations have long possessed great celebrity, in consequence, chiefly, of the numerous virtues ascribed to them. They are resorted to by many votaries of fashion as a panacea against ailments of every kind. They are, however, nothing more than aromatised alcohol, and as such are agreeable companions to the toilet.

Eau de Cologne derives its name from the city of Cologne, on the Rhine, at which place there are annually manufactured about 4,000,000 bottles. Hungary water is said to take its name from one of the queens of Hungary, who is reported to have derived great benefit from a bath containing it, at the age of 75 years. This preparation contains rosemary, which is said to excite the mind to vigorous action.

As will be seen by the following recipes, these waters are similarly constituted and prepared:—

Eau de Cologne—best quality.

Rectified alcohol, 60° over proof	10 gallons.	Essential oil of rosemary	3 ounces.
Oil of neroli of orange	7 ounces.	,, orange zeste	16 ,,
		,, bergamot	3 ,,

Eau de Cologne—second quality.

Alcohol, 50° over proof	10 gallons.	Oil of lemon	5 ounces.
Oil of petit-grain orange	5 ounces.	,, bergamot	5 ,,
,, rosemary	4 ,,		

Hungary Water.

Rectified alcohol, 60° over proof	10 gallons.	Oil of rosemary	6 ounces.
Oil of neroli of lemon	15 ounces.	,, citron zeste	3 ,,
,, petit-grain of orange	5 ,,	,, neroli of orange	2 ,,

Very fine Eau de Cologne and Hungary water can be made by merely mixing the ingredients as indicated in the recipes; but it is far better to mix the citrine essences with the spirit, and then to distil the mixture, finally adding to the distillate the orange neroli and the rosemary.

Both these perfumes are preferred when made with grape-spirit, in lieu of corn-spirit. When, however, corn-alcohol can only be used, its fragrance is greatly improved by the addition of one drachm of acetic ether to every gallon of spirit employed.

(E.) POWDERS.

Inodorous powders, such as starch and talc, are rendered fragrant—

1. By mixing with them odorous flowers, such as orange-blossom, violet, broken

cloves, acacia-buds, &c, allowing them to remain together for 24 to 48 hours, then sifting away the powder from the spent flowers.

2. By the addition of certain ottos, such as rose, lavender, &c., first rubbing a small portion of starch or talc in a mortar with the otto, then mixing this strongly-scented portion with the remainder, by sifting the whole well together in a trough.

In this way is prepared

Rose-Scented Toilet-Powder.

Wheat-starch	14 lbs.
Rose-pink	1 ounce.
Otto of rose	¼ „

The rose-pink and the otto of rose are rubbed well with about 8 ounces of starch, and finally sifted with the remainder as above described.

3. By reducing some fragrant substance, such as cinnamon, nutmeg, or orris-root, to a fine powder, and mixing them with a given proportion of the inodorous starch. The violet-powder of commerce is a good example:—

Infants' Violet-Powder.

Starch of wheat	14 lbs.	Ess. oil of bergamot	½ ounce.
Orris-root powder	3 „	„ almond	¼ drachm.

Sachée Powders

consist entirely of odorous substances reduced to powder, mixed and sifted in various proportions.

Rose-Sachée Powder

consists of

Rose-leaves, ground	1 lb.	Cedar-wood dust	½ lb.
Santal-wood powder	½ „	Otto of rose	1 drachm.

After certain tinctures are made, there is found in the perfume-laboratory a vast quantity of residue, or spent material, such as musk-pods, vanilla, tonquin-beans, ambergris, civet, &c. These spent materials, although not strong enough to yield any perfume to spirit, are yet fragrant, and may be judiciously used in combination with a little otto to produce a good sachée, such as

Olla Podrida,

which consists entirely of spent materials well ground together, and a little otto rose and lavender rubbed in to increase and sweeten its odour.

Frangipanni Sachée.

Orris-root	1 lb.	Grain musk	1 drachm.
Rose-leaves	1 „	Civet	¼ „
Santal-wood	½ „	Otto rose	½ „
Tonquin-beans, ground	½ „		

The civet, the musk, and otto of rose, are to be rubbed well with a little of the orris, and then mixed with the other ingredients; it being understood that all the materials, rose-leaves, orris-root, and santal-wood, have been previously reduced to powder.

Some odorous materials are sold pure, such as patchouli herb, which is merely the leaves of the plant rubbed on a sieve to powder. Santal-wood and orris-root have to be reduced to powder at the drug-grinder's mill.

(F.) SCENTED SOAPS.

Soaps are perfumed by two methods:—

1. By melting the soap in a hot water- or steam-bath, and then adding the scent when the soap is perfectly soft; various kinds and qualities of soap are used for this purpose.

Curd or tallow soap, palm-oil soap, cocoa-nut-oil or marine soap, olive-oil soap, yellow or rosin soap, potash (soft) soap. See SOAP.

When mixed in different proportions, and melted and scented, they bear various fanciful names given to them by the makers, and in some instances indicating their perfume; such as almond and rose soap. No one soap made by the soap-makers appears to give entire satisfaction to the consumer: soaps of oil do not lather sufficiently, or with freedom enough; tallow soaps are too hard; rosin or yellow soap has an unpleasant odour; cocoa-nut soap, being too alkaline, acts upon the skin. The perfumers, therefore, to make a good body soap mix these in various proportions. Thus Piesse and Lubin prepare

Windsor-Castle Soap.

Curd soap	1 cwt.	Grain musk	½ ounce.
Marine soap	21 lbs.	Oil of cloves	of each 3 ounces.
Olive-oil soap	14 „	„ rosemary	
Pale yellow soap	7 „	„ thyme	
Otto carraway	8 ounces.	„ cassia	

The soap is sliced into thin slabs, and put into the steam-pan in proportions of what is termed 'a round,' that is, the slabs are placed perpendicularly all round the side of the pans, so as to be in contact with the metal. In about half an hour this soap will have melted, or 'run down.' Another round is then introduced, and so continued every half-hour, till the whole melting is finished.

The different soaps that are being melted must be put into the pan separately, because they do not all take the same time to liquefy: thus, we must have a round of curd, then a round of marine, then of curd again, varying each time or half-hour; but each round must be of the same sort; the mixture being rendered perfect by stirring the soap with a crutch, or tool like an inverted ⊥, with a long handle. When the melting is finished, the ottos and musk are added; then the soap is turned out into a cooling-frame.

The musk, before being put into the soap, has to be well rubbed in a mortar with a little water, and then passed through a sieve to remove extraneous matters. When new this soap has little fragrance, but when old its 'bouquet' is delightful: the alkaline reaction of soap improves the perfume of the musk.

Brown Windsor Soap

is made of various qualities, generally inferior; the brown colouring added to the soap disguising its *yellow* origin. The scents used for perfuming it are also generally of a common quality, although there are some honourable exceptions.

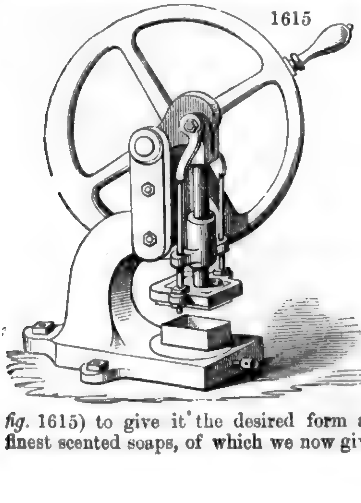
Glycerine Soap.

In consequence of the many virtues attributed to glycerine in a pure state, various soaps under the *name* of Glycerine Soap have been foisted upon the public. It is known to chemists that glycerine is one of the proximate elements of fatty bodies, and that during the saponification of grease it is eliminated as an educt. The better the soap, as a rule, the freer from glycerine. The presence of glycerine in soap is indicative that the soap is imperfectly made. To add glycerine to good soap is, in fact, to spoil the virtues of both articles.

Almond Soap

is made with a mixture of soaps such as is given above; and, when melted, is perfumed with 1 lb. of otto of almonds to every cwt. of soap used. Other fancy soaps are prepared in a similar way; the proportion of perfume regulating the retail price, or *vice versâ.*

1615



2. Soaps are also perfumed by the 'cold process,' as it is termed; that is, the soap is reduced to a state of fine division by shaving it up into a mortar, by putting the bars over an inverted cutting-plane. The best curd soap is generally selected for this purpose. After the soap is reduced to shavings, the scent is well incorporated, and then thoroughly beaten together with a heavy pestle. The soap is then moulded by the hand into lumps of about 4 ounces each, placed on racks to dry for a few days; when sufficiently firm, each lump is placed in the die-press or stamp (see *fig.* 1615) to give it the desired form and lettering. In this way are made all the finest scented soaps, of which we now give a few illustrations :—

Orange-Flower Soap.

Curd soap	7 lbs.
Oil of neroli	2 oz.
Essential oil of orange	2 oz.
Petit grain	½ oz.

Thibet-Musk Soap.

Grained musk	3 drachms.
Curd soap	7 lbs.

The musk is to be powdered with a little starch and sifted through lawn—a work of no little labour—before it is mixed with the soap. The alkaline reaction of soap is favourable to the development of the musk fragrance. It requires, however, fully three months to bring this soap to perfection, and the older it is the better.

Patchouli Soap.

Curd soap	7 lbs.
Essence of patchouli	1 oz.
Bergamot	2 oz.

Otto Rose Soap.

Curd soap (previously coloured with vermilion)	7 lbs.
Otto rose	1 oz.
Indian geranium	½ oz.
„ santal	½ oz.

(G.) COSMETICS, OR TOILET APPENDAGES.

These are rather a numerous class of substances used to 'make up' artificial beauty and the deficiencies of natural imperfections. Whether this be strictly moral or otherwise is not our business to inquire. The practice is, however, sanctioned by its antiquity; and it is in the laboratory of the perfumer those things are made, which, as an old author upon the subject says, 'Can brighten the skin, give force to beauty, and take off the appearance of old age and decay.' There are preparations 'To prevent wrinkles;' 'To make the skin smooth, soft, and glossy;' 'To remove moulds, warts, and longing marks;' 'To improve the complexion, prevent freckles, blotches, and to whiten a tanned or sun-burnt skin;' 'To brighten the eye and increase the memory;' and numerous others, which our limits prevent detailing. We subjoin a few recipes, as examples:—

Milk of Pistachio Nuts, for improving the Complexion.

Spanish Pistachio nuts	4 ounces.
Violet-water	3¼ pints.
Spirit of neroli	¾ pint.
Palm soap Green oil Wax and spermaceti } each	1 ounce.

Dr. Startin, of Saville-row, gives the following recipe as 'an excellent cosmetic':—

Glycerine Lotion.

Orange-flower water	1 pint.
Pure glycerine	1 oz.
Biborate of soda (borax)	1 drachm.

Glycerine Jelly,

which is much approved of in winter seasons as a remedy for chapped hands, and for a dry skin, is made thus:—

Pure glycerine	2 oz.
White soft soap	½ oz.
Almond oil	1 lb.
Scented with otto thyme, otto cloves, and bergamot, each	½ drachm.

The soap and the glycerine are first perfectly blended, then the oil is gradually added, mixing the whole by constant trituration in a mortar; finally, the perfume is added.

Cold Cream of Roses.

This is justly a favourite and universal cosmetic.

Almond oil	1 lb.
Provence rose-water	1 lb.
White wax and spermaceti, each	1 oz.
Otto of roses	½ drachm.

Melt the wax and sperm in the oil, then gradually stir the running rose-water; when nearly finished add the scent.

(H.) DENTIFRICES, PASTES, &c.

Under the general title of Dentifrices, various scented tooth-powders, mouth-washes, tooth-pastes, breath-lozenges, are included in the perfumer's repertory.

Piesse and Lubin's Tooth-Powder.

Precipitated chalk	1 lb.
Orris-powder	1 lb.
Carmine	¼ drachm.
Very fine powdered sugar	¼ lb.
Otto rose and neroli, each	1 drachm.

Opiate Tooth-Paste.

Honey	½ lb.
Precipitated chalk	½ lb.
Orris-powder	½ lb.
Tincture of opium and myrrh, each	¼ oz.
Essence, cloves, nutmeg, and rose, each	½ drachm.

(I.) FUMIGATING PERFUMES.

The earliest records of 'sweet savours' show us that sweet smells were produced from throwing volatile and odorous resins on to a smouldering fire; and so much were they prized that they were considered worthy offerings to the MOST HIGH. The formula for incense for holy places is given in Exodus xxx. 34. The following is a pleasing incense:—

Santal wood in powder	1 lb.	Gum benzoin powder	½ lb.
Vitivert in powder	1 oz.	Grain musk	½ oz.
Cascarilla bark	½ lb.	Powdered nitre	2½ oz.

Ribbon of Bruges, for sweet fumigation.

Make a solution of saltpetre, *i.e.* nitrate of potassa, of 2 ounces to a pint of water; into this steep good undressed cotton tape, then hang up to dry; now steep it in the following tincture which has stood one month:—

Spirit	½ pint.	Myrrh	½ oz.
Musk	½ oz.	Orris	½ pin
Otto rose	1 drachm.	Benzoin	4 oz.

When dry it is fit for use; light it, blow out the flame, and as it smoulders, a fragrant vapour will rise into the air.

(K.) FLUIDS, POMADES.

Unguents for the hair are prepared in endless variety. The following are good examples:—

Philocome.

Enfleurage oil of any or mixed flowers	1 lb.
Virgin wax	3 oz. in summer;

or, in winter, one-third less.

Crystallised Oil.

Enfleurage oil of any flower	1 lb.
Spermaceti	2 oz.

Cool gradually.

Hungarian Pomade.

(Pour moustache à la Crinoline.)

White wax	1 lb.	Rose-water	1 pint.
Oil soap	½ lb.	Bergamot	1 oz.
Gum arabic	½ lb.	Thyme	1 drachm.

Hair-washes are for cleaning the head, and removing effete pomade.

Spirit	1 pint.
Marine soap	1 lb.

Melt the soap in the spirit in a bath, then add rose- or orange-water, ¼ pint.

Athenian Hair-wash.

Rosemary-water	1 gallon.
Sassafras chips	$\frac{1}{4}$ lb.
Pearlash	2 oz.

Boil for half an hour; when cold, add spirit or Hungary-water, 1 pint.

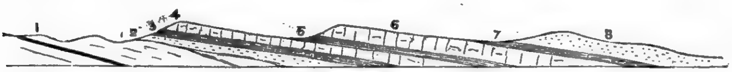
(L.) Several other products of the perfumer's laboratory, such as hair-dyes, fixateur, depilatory, court plaster, &c.; but these cannot be well taught by books.—S. P.

PERFUMERY, INDIAN. The natives place on the floor a layer of the scented flowers, about 4 inches thick and 2 feet square; cover them with a layer 2 inches thick of *Tel* or Sesamum-seed wetted; then lay on another 4-inch bed of flowers, and cover this pile with a sheet, which is pressed down by weights round the edges. After remaining in this state for 18 hours, the flowers are removed and replaced by a similar fresh layer, and the seeds are treated as before; a process which is repeated several times if a very rich perfumed oil be required. The sesamum-seeds thus embued with the essential oil of the plant, whether jasmine, bela, or chumbul, are placed in their swollen state in a press, and subjected to strong pressure, whereby they give out their bland oil strongly impregnated with the aroma of the particular flower employed. The oil is kept in prepared skins called *dubbers*, and is largely used by the Indian women. Attar of roses is extensively produced at Ghazepore, and is obtained by distillation.

PERIDOT. A jeweller's name for the transparent green chrysolite (olivine), cut as an ornamental stone. See Chrysolite.

PERMIAN. The Permian rocks were so called by Sir Roderick Murchison, from the Government of Perm, in European Russia, where these rocks are largely developed. They had previously been termed the Lower New Red series. As, however, these strata have nothing in common with the New Red Sandstone, except occasionally colour, and as the magnesian limestone is often absent, the word 'Permian' now generally supersedes the older denomination. The Permian rocks form the uppermost member of the Palæozoic strata, lying, when the series is complete, on the Upper Coal Measures. They skirt the carboniferous rocks on the east uncomformably, from Nottinghamshire to the river Tyne; and where complete the section is as in *fig.* 1616, in Nottinghamshire and South Lancashire.

1616



1. Coal-measures.

Permian rocks
2. Red and variegated sandstone and conglomerates.
3. Marly shale, 'marl slate.'
4. Magnesian limestone, often sandy.
5. Red marl.
6. Thin bedded magnesian limestone.
7. Red marl.

8. New Red Sandstone.

The sandstone, 2, contains plant remains, and the limestones, productas, spirifers, nautili, and other marine shells of Palæozoic types. It is from the Lower Limestone that the stone for building the Houses of Parliament was obtained. It forms frequently an excellent building stone, and may be obtained in places in blocks of great size. It is also extensively burned for lime.

Permian strata, believed to belong to the sandstone beds, No. 2, surround more or less the Lancashire, North and South Staffordshire, the Warwickshire, and the Shropshire coal-fields, &c. They are in places 1,000 feet thick, and consist chiefly of red marls, sandstones, and conglomerates. The Magnesian Limestone is generally absent in these districts; but thin bands of it occur in Lancashire, and in parts of Cumberland.

There are *magnesian limestones* in other formations, not to be confounded with those of Permian age.—A. C. R.

PERNAMBUCO WOOD. See Brazil Wood.

PERRY is the fermented juice of pears, prepared in exactly the same way as Cyder.

PERSIAN BERRIES. See Berries, Persian.

PERUVIAN BARK, or *Jesuits' Bark.* The products of several species of the *Cinchona.* For a knowledge of the medicinal properties of the Peruvian bark, and its value in curing intermittent fever, we are indebted to the Jesuit priests, who introduced it to Europe in 1632; but it was not commonly used till the latter part of the seventeenth century. The disulphate of quinine is largely prepared from this bark, of which we imported in 1873 as follows:—

	Quantity Cwts.	Value £
From France	1,110	7,845
" Central America	1,228	12,280
" New Granada	11,843	106,617
" Ecuador	4,668	44,597
" Peru	5,829	74,643
" Chili	1,782	23,453
" Brazil	146	1,387
" Other countries	1,845	14,798
Total	28,451	285,620

Of which we re-exported 11,424 cwts. to the value of 71,304*l*.

PETALITE, from *πέταλον, a leaf*. The mineral in which lithia was first discovered by Arfvedson. Petalite occurs in the iron mine of Utö, Stockholm; near York, on the north coast of Lake Ontario; at Bolton, Mass., U.S.; and at Elba. Its composition is, according to Rammelsberg:—silica, 77·79; alumina, 18·58; lithia, 3·30; soda, 1·19 = 100·86.

PETROLEUM. (*Pétrole*, Fr.; *Steinöl*, Ger.) This term is applied to several fluid bituminous substances, found in a great number of different localities, in rocks of very dissimilar ages, and which were formerly known as Persian naphtha, or rock-naphtha. (See NAPHTHA.) As it, however, forms only one of a numerous class of analogous compounds, it will be convenient to take a general view of the whole class of bituminous minerals occurring in nature. Starting with the liquid compounds, which, as a rule are, in composition isomeric with olefiant gas, and may be represented by the formula C_nH_n, the diminution of hydrogen is accompanied by an increase of density, until we reach the more bituminous varieties of coal. The following table, by Dr. Sterry Hunt, represents the intermediate steps of this series; the analyses are computed with 24 equivalents of carbon, in order to compare them with cellulose, $C^{24} H^{20} O^{20}$:—

Liquid bitumens; general composition	$C^{24} H^{24}$.
" " Rangoon petroleum	$C^{24} H^{26}$.
Elastic bitumen or Elaterite; Derbyshire	$C^{24} H^{22} O^{0.8}$
Asphalt, Bastennes	$C^{24} H^{16} O^{0.7}$
" Naples	$C^{24} H^{15} O^{2}$.
" Mexico	$C^{24} H^{17} O^{2}$.
Idrialine	$C^{24} H^{8}$.
Albertite or Albert coal; New Brunswick	$C^{25} H^{16} O^{2}$.
Bituminous or resinous lignite	$C^{24} H^{15} O^{3}$.
Bituminous coal, extremes of composition	$C^{24} H^{8} O$. $C^{24} H^{10} O^{4}$.

From the above table, it will be seen that certain bitumens, such as Idrialine, differ but slightly in composition from bituminous coals, and in reality it is very difficult to draw a decided line between them. The questions as to whether certain Scotch cannel coals and the Albert coal of New Brunswick, are to be considered as coal or not, have been discussed at great lengths before courts of law, without leading to any satisfactory definition. Roughly speaking, the characters of fusibility and solubility in benzole and sulphide of carbon are to be relied on as distinguishing the solid bitumens from coals.

According to Boussingault, asphalt is a dark brown or pitchy-black substance, fusible at the temperature of boiling water. At lower temperatures, when perfectly solid, it breaks with a well-marked conchoïdal fracture. Hardness, 2; specific gravity 1·1 to 1·2. It becomes negatively electric by friction, giving out a strong and characteristic bituminous odour. When asphalt is treated with anhydrous alcohol, about 5 per cent. of a resin is extracted, which is called by Boussingault *Petrolete*. From the remaining 95 per cent. insoluble in alcohol, ether dissolves 70 per cent. of a black resin, giving a brown solution. The whole of the remaining 25 per cent. is soluble in rock-naphtha or ethereal oils, and has been termed *Asphaltene*. Its percentage composition is: carbon, 75·5; hydrogen, 9·9; and oxygen, 14·8 or approximately of the atomic formula, $C^{28} H^{20} O^{4}$, which, according to the preceding table, is intermediate between asphalt and elaterite.

Among the more important localities of bituminous matters, are the following:—Sandstones and limestones filled with asphalt, in greater or less abundance, of the age of the Molasse, or Middle Tertiary period, are found at Seyssel, in the French department of the Rhine; also in the Val de Travers, in Neocomian limestone. The bituminous sand of Bechelsbronn, in Alsace, which is of tertiary age, is about 7 feet thick, containing 2 per cent. of bitumen. Similar sands are found at Soultz-sous-Fôrets, and Schwabsweilier, in the same country. At Lobsann, also, in Alsace, Daubrée has described a freshwater tertiary limestone, which contains 10, 12, and even at times 18 per cent. of bitumen. Similar deposits exist in Otago, N.Z. Bitumen also occurs in sandstone in the Auvergne, in Central France.

Bitumen is occasionally found in mineral veins, as, for instance, at Dannemora and Filipstad, in Sweden, accompanying magnetite, and in the carboniferous limestone at Staunton Harold, in Leicestershire, in small veins associated with galena, copper-, and iron-pyrites. It also occurs in brown iron ores, at Markolden and Markoldendorf, near Hildesheim; and at Elligsér Brink, in Brunswick. An analogous mode of occurrence is furnished by *Hatchettine*, or mineral tallow, a beautiful pearly-white substance, almost identical with paraffin, which is found in the interior of nodules of clay-ironstone in the neighbourhood of Merthyr Tydfil. *Ozokerite* is a similar substance, of a darker colour, found in sandstones both in Scotland and in Galicia and Moldavia. *Idrialine* is remarkable as being a hydrocarbon, containing a minimum amount of hydrogen: it occurs in a bituminous schist, which contains cinnabar, at the great quicksilver mine of Idria, in Carniola. A remarkable substance, forming apparently a link between lignite and asphalt, has been described by Delesse. It is a brownish-black rock, of a very compact texture, found at Promina, in Austria, containing 59 per cent. of crystalline carbonate of lime, 9 per cent. of argillaceous matter, and 32 per cent. of a combustible substance, which is fusible but almost totally insoluble in benzine. When heated it gives off acid vapours, leaving only 3½ per cent. of coke. See ASPHALT; BITUMEN; OZOKERITE.

The so-called *Pyropissite* of Kengott is another mineral intermediate in character between lignite and bitumen. It is a dark yellowish-grey, or brown, earthy, and friable substance, with a shining streak, of the specific gravity 0·9. When heated it gives off a dense white smoke, and melts to a pitchy mass. A waxy substance of a very complex composition may be extracted from it by digestion in ether, and Marchand obtained 62 per cent. of paraffin from the natural mineral by dry distillation. The principal localities are Gerstewitz near Weissenfels, and Helbra in Thuringia, where it forms a layer of 3½ feet in thickness, immediately above a seam of brown coal.

Dysodil is another bituminous mineral associated with brown coal, but this term appears to be applied to two different substances: one being an infusorial earth saturated with mineral tallow, found near Giessen, in Hesse-Darmstadt, while on the lower Rhine the term is applied to a lamellar brown coal. See DYSODIL.

Turba, a very light material, greyish or brownish in colour and felty in texture, which ignites readily with a dense smoky flame, leaving the mass of the same dimensions as before, occurs in abundance at Camamú, province of Bahia, Brazil. Hartt (Hartt's 'Scientific Results of Agassiz's Journey to Brazil,' p. 262) states that it rests in a basin of gneiss whence the tertiary clays have been swept away; hence it appears to be of recent origin. In a section of 108 feet the turba intermingles with a series of arenaceous and argillaceous sandstones, alternating with bituminous clay, lignite, shale, and sometimes pure bitumen; it usually rests on limestone, a conjunction peculiar to petroleum and shales. Prof. Edwards considers the turba not a sub-aqueous deposit, as it contains no diatoms, and its enclosed fossils are wood, a few leaves, and fibres like fine roots. It has yielded from 50 to 100 gallons of oil per ton on distillation.

The Rev. Mr. Clarke of Sydney, N. S. W. ('Journ. Geol. Society,' vol. xxii. p. 447), speaks of the *Bournda deposit* near Cape Howe being probably of recent origin. Like the Brazilian deposit just described, this also consists of a series of clays and blackish mud, alternating with lignite. It, too, has been formed in a lake near the sea-beach. A white waxy substance like bog butter was found to the north of this last-described deposit some years ago. It yielded on distillation 8·6 per cent. of crude oil, which again yielded on subsequent distillations 35 per cent. of burning oil, lubricating oil, and paraffin.

Large deposits of petroleum and its associated minerals have been discovered along the course of the chalk of North Germany, at its junctions with the sands which cap it. Indications have been seen near Hamburg, Hesse-Darmstadt, Ruttsdam, and other places. On the banks of the Rhine a bed of *Albertite* is being worked for oil-making; it is said to yield 120 gallons to the ton in laboratory experiments. Principal Dawson now relegates Albertite from the class of gas-coals into that of the petroleums. (See 'Acadia,' 2nd ed.) See also ALBERTITE.

Springs of mineral oil, or liquid petroleum, are found in almost all localities where bitumen or asphalt exists in quantity in the rocks; many of these localities have been known from time immemorial: such as, for instance, the Rangoon wells, and those of

Persia and the Caspian Sea. It is only within the last few years, however, that the largest source of supply in the north-eastern states of America and Canada have been developed, although the existence of petroleum in Pennsylvania (where it was collected and sold by the Seneca Indians, under the name of Seneca oil) has been known for a very long period. Many different bituminous formations are known at different horizons in the palæozoic rocks of America; in the Silurian series traces of the former existence of bitumen are afforded by the occurrence of shining anthracitic substances in cracks and fissures in the Quebec group, and its equivalent, the Calciferous sand-rock, at several localities in Eastern Canada and the State of New York. In the Trenton limestone, liquid petroleum is found in the chambers of the larger orthoceratites, some of these fossils containing at times several ounces of oil; and a spring yielding small quantities rises from the Utica slate on Great Manitoulin Island, on Lake Huron. A more important but as yet scarcely developed locality, probably at the top of the Silurian series, is in the peninsula of Gaspé, in the easternmost part of Canada. It is, however, from the Devonian rocks that the greatest quantities of petroleum are derived in America. At Oil Springs and Enniskillen, near Sarnia, Canada West, natural oil-springs occur upon the outcrop of the Corniferous limestone, or the overlying Hamilton shale, along the line of a broad and low anticlinal traversing the district in a nearly east-and-west line, both formations being generally covered by from forty to sixty feet of drift and alluvial clays and sands. At the Wyoming Company's wells, the overflow of the natural springs, rising through the superficial beds, have produced deposits of hardened and slightly elastic bitumen or asphalt, which are locally known as 'gum-beds.' They are somewhat irregular in thickness, varying from a few inches to two feet, and cover an area of about two acres. According to Delesse, this substance fuses at 180° Fahr. and contains 62½ per cent. of bitumen, soluble in benzole; 24·8 per cent. of organic matter, the remains of plants which have grown upon the present surface, and have become imbedded in the 'gum'; and 12·7 per cent. of clay and sand. The occurrence of these beds is instructive, as showing how bituminous rocks may be formed by the gradual drying-up and oxidation of liquid petroleum. When wells are sunk in the overlying clays and sands, there is usually found, at the junction with the shales, a bed of coarse gravel holding large quantities of oil of a treacly consistency and dark colour. This is the oil of the surface-wells, so called from their being situated entirely in superficial deposits, as distinguished from the rock-wells, which are bored into the Hamilton shales and Corniferous limestone strata below. It has a very offensive smell, but is actually of greater value than the more limpid product of the rock-wells, being sold without any further preparation as a lubricating medium for the axles of railway-carriages. The rock-wells are of two characters, namely, 'pumping' and 'flowing:' the former being mostly intermittent in their discharge, and requiring the aid of machinery to bring their contents to the surface, while in the latter the oil rises, like water in a true artesian well, above the level of the surface; the free discharge being, however, due not to hydrostatic pressure so much as to the elastic force of light carburetted hydrogen gas, which is almost always present in oil-wells. Unlike wells sunk for water, the gathering-ground of an oil-well is extremely local, being probably confined to a lenticular belt of porous rock in its immediate neighbourhood; and when this is exhausted, the supply fails: and unless the hole be bored deeper, on the chance of striking another vein in depth, it is abandoned for a fresh locality. The first great flowing-well at Enniskillen yielded 1,500 barrels when first struck, the greater part of which, for want of sufficient collecting vats, overflowed into the valley of the neighbouring brook, and was lost; but in a short time it was exhausted. The best wells in this locality, in July 1865, yielded about 100 barrels, or 4,000 gallons each, daily; but only five were in this category, the greater number not exceeding 10 or 20 barrels. The Wyoming Company's wells, 9 in number, sunk on the gum-beds, yielded from 5 to 6 barrels each, per day, at the same period. It was computed that the working expenses of a well, pumped by steam-power, could be covered by a yield of a single barrel daily. The conditions under which petroleum occurs in Pennsylvania, are somewhat similar to those observed in Canada, but on a somewhat higher geological horizon; the chief oil-bearing rocks being the sandstones, limestones, and slates, overlying the Hamilton and Genesee groups. The deepest wells in Oil Creek, the principal Pennsylvanian locality, are supposed to be in the Portage, while the shallower ones are in the Chemung group, both members of the Upper Devonian series. At the commencement of the year 1865, in the district of Oil Creek, Pennsylvania, 480 wells were already sunk, and 542 more were in progress of sinking, within an area of 5 square miles. Of these, 189 produced oil, the total estimated yield being 4,000 barrels, or 160,000 gallons daily. Some of the earlier wells, sunk in the year 1861, at first yielded from 600 to 3,000 and 4,000 barrels each, daily, but in no instance have these great yields been kept up for more than a few months: the maximum yield at the date alluded to appears to have been about 325 barrels. The MacKinley well, in the same locality, is noticeable on account of its uniformity of yield, amounting to between 50 and 60 barrels per diem, which production has been steadily maintained without pumping for nearly 3 years.

The uppermost Devonian or Catskill group has as yet given rise to no wells of any importance. The subcarboniferous or mountain limestone, and the lower carboniferous rocks of the United States are devoid of petroleum; but in England, traces of the presence of bitumen are found in the mountain limestone in Shropshire, at Castleton in Derbyshire, and at Staunton Harold in Leicestershire. In the lower coal-measures, oil-wells are found in Ohio and Virginia, and also in the upper coal-measures at Marietta, in the former state. A spring of actual petroleum was discovered some years ago in the coal-measures at Alfreton in Derbyshire; and while the supply lasted, it was employed in the manufacture of paraffin and lubricating oils.

In the secondary rocks, solid and liquid bitumen occur at many different points, but not in the extraordinary quantities that characterise the palæozoic rocks of America; among other localities may be mentioned Deestadt and Sickle, in Brunswick, where it occurs in the lias shales; and Edimissen and Odensee, in Hanover, where springs of petroleum rise from the middle beds of the Wealden series, which are also coal-bearing. In England, the lias jet-rock of Whitby, and the Kimmeridge shale of Dorsetshire, are examples of bituminous rocks belonging to the secondary period. The petroleum of California is derived from rocks of cretaceous, or perhaps tertiary age.

One of the most interesting of the tertiary petroleum districts is that of Galicia, on the northern slope of the Carpathians. This, according to Von Hochstetter, extends N.W.—S.E. for about 200 miles, along a line of fractures parallel to the main chain of mountains, through which fractures petroleum rises on account of the gaseous pressure below, and saturates the overlying brecciated rocks and sandstones, which are of eocene age. The wells actually sunk are square shafts, which often pass through a peculiar breccia of fragments of bituminous shale, angular pieces of asphalt, quartz grains, and flakes of mica, cemented by calc-spar. The rock generally is a sandy shale. In one of these wells, at 2 fathoms deep, the cracks of the rock were found to be filled with a white bitumen like Hatchettine, and in the third fathom petroleum appeared in drops, which filtered through the walls, and collected at the bottom of the shaft. The oil is so full of paraffin, that it is only when a certain quantity of water issues with it out of the rock, that any quantity is collected. Samples collected from five different localities varied in specific gravity from 0·803 to 0·920, the latter being surface-oils collected from a pool of water. The lighter varieties contain so much paraffin as to solidify at a temperature of 50° F. The relation between the West Galician oil, rising from eocene rocks, to that of Eastern Galicia, which is obtained from miocene strata, is similar to that existing between the Pennsylvanian and Canadian oils—the latter in either case being dark in colour, and less fluid than the former. The Wallachian oil is also dark coloured, and is associated with ozokerite or paraffin, in a similar manner to that of Galicia. Another and better-known deposit of petroleum in tertiary strata is that in the Island of Trinidad, which has been described at considerable length by Mr. G. P. Wall, in his 'Report on the Geology of Trinidad.'

The methods employed in America for boring oil-wells are usually of a very simple character, and do not differ very much from those used in this country for trial-borings in the coal-measures. As a rule, a rope is used for suspending the boring-bar, instead of rigid rods; the lower parts of the arrangement, known as the augur-bar and sinker-bar, weigh from 7 to 9 cwts., and are united by a simple gliding piece, called the 'jars,' which is, in fact, an application of the free-falling cutter used in deep borings in Europe. The detritus is removed by the shell- or sand-pump, in the ordinary way. A modification of Fauvelle's system, having hollow rods with a continuous discharge of the detritus, was at one time in use at Oil Springs, Canada West. The boring-bit has a hollow stem, the cutting edges being formed by three stout radiating pieces of steel. In the angle formed by these pieces, and their junction with the stem-brass, valves are inserted which allow the detritus to enter the rod through which it rises, and is discharged in jets at every fall of the cutter. The lifting of the borer is effected by toothed levers, similar to those of a safety-catch used in collieries, which fall together by their own weight, and take hold of the rod at the end of the stroke; and are released by tappets attached to the boring-frame or derrick, striking against their outer ends when the rod is at the top of its stroke. The boring is usually performed by steam-power, the upper end of the rope being secured to the outer arm of a vibrating or 'walking' beam, receiving motion by means of a strap and pulley from a small steam-engine of about 1 or 2 horse-power. When the boring is finished, the same arrangement is used to work the oil-pump. The use of the intermediate beam and driving-belt allows the boiler, which is usually of the common agricultural or portable form, to be kept at a safe distance from the stream of inflammable gas, accompanying the oil and water brought up. The mixed fluid lifted by the pump is received in large open vats, in which the separation takes place; the water being allowed to run off by a waste-pipe below, while the oil accumulates until a sufficient quantity has been collected for barrelling. The standard measure for petroleum is the barrel of 40 American or old wine-gallons, equal in weight to about 3 cwts.

From what has already been stated, it will be easily understood that petroleum varies considerably in composition and density, according to whether it be derived from shallow or deep wells, the former giving the darkest and heaviest products. The following are some of the chief properties of different American oils, according to Gesner:—Pennsylvanian petroleum is dark coloured, with a peculiar greenish lustre or fluorescence; by reflected light, the specific gravity varies from 0·782 to 0·820. When refined, the distillate yields from 75 to 85 per cent. of illuminating oil, giving off inflammable vapours at a temperature of from 110° to 116° F. The heavy oils produced in the distillation yield paraffin, or may be used for lubricating. The specific gravity of heavy natural or lubricating oil from Pennsylvania, is from 0·800 to 0·860.

Oil from Mecca, Ohio, which remains fluid at very low temperatures, has the specific gravity 0·890 to 0·910. The Canadian or Enniskillen petroleum is dark coloured, and has a peculiar and very offensive smell, but yields a larger quantity of burning oils than the Pennsylvanian; its specific gravity is from 0·860 to 0·880; that of the rectified burning-oil is 0·838. A sample of Californian petroleum, of the specific gravity 0·927, yielded the following products when refined:—

Illuminating oil	38 per cent.
Lubricating oil	48 ,, ,,
Pitch	10 ,, ,,
Water	4 ,, ,,

Another sample from California lost from 10 to 15 degrees by volume, yielding, on rectification:—

	Per cent.
Light oils	5
Burning oil	50
Light machine-oil	20
Heavy oil and paraffin	25

The bitumen of the gum-bed of Enniskillen yields 50 per cent. of volatile products by distillation; and the Rangoon tar contains about 10 or 11 per cent. of paraffin.

The refining of petroleum has already been noticed under NAPHTHA. The following is a sketch of the operation as performed at a small refinery at Oil Springs, Canada West. The crude oil, purchased from the proprietors of the wells, is stored in large underground tanks. For refining, wrought-iron stills are employed, having a capacity of 40 barrels, or 1,600 gallons; they are flat-bottomed, and are provided with man-holes, through which the black pitchy residue is removed. When the charge is introduced the still is closed, and the distillation is effected by a fire placed beneath. The charge takes about a week to work off; the distillate is collected in large wooden tubs, a small quantity of a thick greenish substance separating from it, which is returned to the still. The pitchy residue in the still is not subjected to any further treatment, but forms part of the fuel used in the next distillation. The liquid collected is mixed with from 5 to 10 per cent. of sulphuric acid, and agitated by rotatory paddles at a steam-heat, for the purpose of bleaching it. After this is done, the bleached oil is washed with water, the last faint traces of acid are neutralised with caustic potash, and it is finally deodorised with ammonia. When freshly prepared, the refined oil is without colour or smell; and when seen in large quantity, exhibits the extraordinary blue, or fluorescent rays of Professor Stokes in a striking manner. The loss in distillation is about 30 per cent.; the refined oil is packed in 40-gallon barrels made of oak, which, before they are used, are lined with an elastic cement resembling vulcanised india-rubber, the principal ingredients of which are glue and white lead, in order to prevent leakage through the joints of the staves.

The gigantic dimensions of the American petroleum trade may best be represented by the following statistics given in evidence, before a Select Committee of the House of Lords, in 1872:—

Exports from the United States during the years 1870 *and* 1871, *to London and several Continental ports, in gallons.*

	1870	1871
London	2,047,118	1,457,628
Bremen	10,162,399	12,356,572
Hamburg	4,456,226	5,780,459
Rotterdam	5,305,299	6,987,302
Königsberg and Stettin	2,665,677	5,600,978
Copenhagen	894,422	2,967,345
Genoa and Leghorn	2,515,926	3,109,142

The petroleum *Exports* of the United States for 1872 were as follow:—

During the year there had been exported 170,385,869 gallons; the most of it going to German ports. This, compared with 1871, is a decrease of over 5,000,000 of gallons; this decrease in a trade which naturally ought to increase being accounted for by the strenuous efforts which have been made to control the trade and prices by decreasing production at the wells. These efforts still continue, though they are looked upon as unsuccessful. The bulk of the export is made from New York and Philadelphia; the former having sent out 90,000,000, and the latter nearly 57,000,000 gallons during the year, leaving but 3 per cent. of the export for other ports. Philadelphia, compared with 1871, increased her export nearly 750,000 gallons; while that of New York was reduced nearly 5,000,000 of gallons. Owing to certain trade advantages in favour of Philadelphia, her export gradually increases at the expense of other ports. Year by year a larger portion of the petroleum shipped is refined oil; nearly 128,000,000 out of the 150,000,000 gallons sent in 1872 having been refined oil.

Total exports from United States to all parts of the world during the years—

	Gallons
1868	97,013,817
1869	100,780,158
1870	139,271,450
1871	154,877,377

The high prices of petroleum in Europe when first used as an illuminant, stimulated production to an extraordinary extent. This was also aided by the cheapness of manufacture; pumping, purification, and cooperage being very easy items. When Young's burning-oil sold retail at 3*s.* 6*d.* per gallon, and when 1*s.* 6*d.* was the lowest quotation looked on as possible, it was seriously doubted that the Americans could compete with British oil-makers at the lower figure. But several years' experience has shown how petroleum can be profitably exported at a price in Europe below this. In fact, the safest petroleum is now sold so low as to allow the working-man a light superior to gas at 1*d.* a night. Our statistics show how decrease in price has only stimulated activity in production. Notwithstanding the lull at the commencement of last season's trade, caused by a temporary combination amongst the well-owners, it heads the yield of all previous years. Though really coextensive with the area of the North American continent, petroleum is chiefly got in Pennsylvania, West Virginia, and Ohio, in the United States; as also in Western Canada. Its proximity to immense metallic deposits in many localities encourages the hope of its speedy use in metallurgy. Less than half of the crude material can be safely sold for lamps, but it would admirably answer this purpose. (See NAPHTHA, NATIVE.) Most of the refined material reaching Europe is obtained in county Venango in Pennsylvania, in the neighbourhood of Oil City, Titusville, Petroleum, Cherry Run, &c. There are now few or no flowing wells in the oil regions; but, owing to various circumstances, the oil-well owner can compete very favourably with the British mineral-oil maker. British crude shale-oil, in the most favourable circumstances, was manufactured at a prime cost of 3¾*d.* per gallon; now (1873) it costs nearly double. Pumping an oil-well should not cost more than ½*d.* per gallon. The bore-holes which are made through the heavy honeycombed structure of the sandstones of Oil Creek, U.S., are from 3 to 4 inches in diameter, and frequently 500 or 600 feet deep, sometimes 800 feet deep. From many years' experience, the cost of sinking a bore-hole nearly 900 feet deep, and preparing everything to pump up the petroleum, is 4,000 to 5,000 dollars. Now in 1869 some of the best-yielding bore-holes gave much more than 250 to 300 barrels per day, but at the close of the year only one of these bore-holes continued yielding 200 barrels a day; whilst thirty were giving from 50 to 100 barrels per day. Assuming the Titusville standard of 43 gallons per barrel, it would cost 7,000*l.* sterling to fit up a shale-work giving the lowest yield; and the profits would be fractional compared with those of the oil-well. This competition has driven the crude-oil trade of Britain into the hands of large capitalists. But the oil-maker calculates on the gross profits of a large turn-over, and on his advantage over his Pennsylvanian competitor in having sulphate of ammonia, paraffin, and other ore-products. The enormous quantity of used petroleum-barrels in the British market is also a great source of profit. . . . .

As regards the origin of petroleum and analogous bituminous substances, there can be but little doubt that they are derived from the decomposition of organic matter in the rocks containing them. The changes forming part of the great series whereby organised structures, containing carbon, oxygen, and hydrogen, become altered into peat, lignite, coal, anthracite, and graphite, are too well known to be dwelt upon here at length; suffice it to say, that they consist in the abstraction of variable quantities of carbonic acid, water, and marsh-gas (C^2H^4). From the results of observations of the Geological Survey of Canada, Dr. Sterry Hunt, Mr. Wall, and others, it would appear that the separation of these hydrocarbons is the first stage of carbonaceous metamorphism, and that such substances when under favourable conditions—that is, when kept from the access of air, as in the cavities of limestones, or in sandstones or shales covered by impermeable beds—may be preserved intact; but when they are allowed to come to the surface (as, for instance, in rising through cracks and superficial gravels) oxidation takes place, the greater part of the hydrogen is removed, and ultimately asphalt and coaly substances are produced. That much of the petroleum of the older rocks may be derived from the decomposition of animal matter is evident by its presence in considerable amount in the cells of coral, in Corniferous limestone, which contains exclusively marine remains, and is not permeable to liquids from without. In peat and brown coal there is no difficulty in supposing that the decomposition of the plants has given rise to the various paraffin-like and other solid hydrocarbons which it contains. One particular class of these substances—namely, the resins, such as amber, retinite, &c.—may have existed in the tissues of the plants during their life, as they may all be paralleled with the gum-resins of living conifers. Perhaps the most remarkable among these bitumens is that called *Scheererite*, found in the brown coals of Uznach in Switzerland, and Eger in Bohemia; which, while resembling Hatchettine, has the composition of marsh-gas, showing the same relation to it that paraffin does to olefiant gas.

Another fact in support of the animal origin of some bitumens is that furnished by the bituminous odour evolved by nearly all very fossiliferous limestones, as, for instance, the Upper Silurian and Carboniferous limestones of England, which certainly contain no land-plants.

Another view, put forward by Dr. Senft, may be of use in explaining why in certain cases coals are produced and in others bituminous shales: it is, that the carbonaceous substance produced in peat-bogs has the power of absorbing and fixing carburetted and sulphuretted hydrogen. Now, supposing in a sea-bed the amount of decomposing organic matter, marine plants, molluscs, corals, &c., to be small as compared with the accompanying mineral matter (carbonate of lime, silica, clay, &c.), the hydrocarbons formed would be liable to escape, and remain isolated as petroleum. But, on the other hand, in the case of a great forest-growth or peat-bog decomposing under water, the hydrocarbons separated would be liable to be reabsorbed by the great excess of residual carbon present, and to be condensed, giving rise to bituminous coals. See NAPHTHA; PARAFFIN.

Petroleum Imports in 1873.

	Tuns	Value £
Unrefined, from the United States of America .	895	12,836
	Gallons	£
Refined, from the United States of America .	16,377,252	974,755
,, other countries	58,548	5,250
Total . . .	16,435,800	979,005

Imports in 1874.

85,630 tuns; value £1,002,541.

(For further information on this subject, consult Sterry Hunt's paper in 'American Journal of Science,' vol. xxxv. p. 158; *Senft, über Humus, Torf*, &c.; Gesner on 'Coal Oils'; and *Rammelsberg, Mineral-Chemie.*)

At the old rates of wages and coals, the crude oil yielded a moderate trade-profit in competition with petroleum; but this summer (1873) many British companies have considerably reduced their dividends. And the stability of our home trade will depend on increased economies in fuel, mining, and labour. On the other hand, the abundance of petroleum in America, and the ease with which it is obtained, will, unless new uses for the material are discovered, keep the trade only barely lucrative.

PE-TUN-TSE is the Chinese name for what is thought by geologists to be a partially-decomposed granite, used by them in the manufacture of their porcelain. It is analogous to our Cornish china-stone. See CHINA STONE; CLAY.

PETWORTH MARBLE. A shelly limestone, occurring in the Wealden strata, in the neighbourhood of Petworth, in Sussex. See SUSSEX MARBLE.—H. W. B.

PEWTER. (*Potier d'étain*, Fr.) Pewter is, generally speaking, an alloy of tin and lead, with a little antimony or copper, combined in several different proportions, according to the purposes which the alloy is to serve. The English pewterers distinguish three sorts, which they call *plate*, *trifle*, and *ley* pewter: the first and hardest being used for plates and dishes; the second for beer-pots; and the third for larger wine measures. The *plate pewter* has a bright silvery lustre when polished; the best is composed of 100 parts of tin, 8 parts of antimony, 2 parts of bismuth, and 2 of copper. The *trifle* is said by some to consist of 83 parts of tin, and 17 of antimony; but it generally contains a good deal of lead. The *ley pewter* is composed of 4 parts of tin and 1 of lead. The English ley pewter contains often much more than 20 per cent. of lead. As the tendency of the manufacturer is to put in as much of the cheap metal as is compatible with the appearance of his alloy in the market, and as an excess of lead may cause it to act poisonously upon all vinegars and many wines, the French Government appointed Fourcroy, Vauquelin, and other chemists, to ascertain by experiment the proper proportions of a safe pewter alloy. These commissioners found that 18 parts of lead might, without danger of affecting wines, &c., be alloyed with 82 parts of tin; and the French Government in consequence passed a law, requiring pewterers to use 83½ of tin in 100 parts, with a tolerance of error amounting to 1½ per cent. This ordonnance, allowing not more than 18 per cent. of lead at a maximum, has been extended to all vessels destined to contain alimentary substances. A table of specific gravities was also published, on purpose to test the quality of the alloy; the density of which, at the legal standard, is 7·764. Any excess of lead is immediately indicated by an increase in the specific gravity above that number.

Britannia metal, the kind of pewter of which English teapots are made, is an alloy of equal parts of brass, tin, antimony, and bismuth; but the proportions differ in different workshops, and in many much more tin is introduced. *Queen's metal* is said to consist of 9 parts of tin, 1 of antimony, 1 of bismuth, and 1 of lead; it serves also for teapots and other domestic utensils.

A much safer and better alloy for these purposes may be compounded by adding to 100 parts of the French pewter, 5 parts of antimony, and 5 of brass to harden it. Under TIN, will be found the description of an easy method of analysing its lead alloys.

The pewterer fashions most of his articles by casting them in brass moulds, which are made both inside and outside in various pieces, nicely fitted together, and locked in their position by ears and catches or pins of various kinds. The moulds must be moderately heated before the pewter is poured into them, and their surfaces should be brushed evenly over with pounce-powder (*sandarach*) beaten up with white-of-egg. Sometimes a film of oil is preferred. The pieces, after being cast, are turned and polished; and if any part needs soldering, it must be done with a fusible alloy of tin, bismuth, and lead.

It is the practice, however, in the metal works of Birmingham, to raise various articles, as tea-pots, milk-jugs, and the like, from the flat into their proper forms, by a process called SPINNING: this consists in bringing the sheet of pewter against a rapidly-revolving tool, by which, with a little dexterity on the part of the workman, it is gradually fashioned.

PHANTASMAGORIA. The phantasmagoria lanterns are a scientific form of magic lantern, differing from it in no essential principle. The images they produce are variously exhibited, either on opaque or transparent screens. The light may be a kind of solar lamp, but in most cases the oxyhydrogen or lime light is now employed. The manner in which the beautiful melting pictures called dissolving views are produced, as respects the mechanism employed,, deserves to be explained. The arrangement adopted in the instrument is the following:—Two lanterns of the same size and power, and in all respects exactly agreeing, are arranged together upon a little tray or platform. They are held fast to this stand by screws, which admit of a certain degree of half-revolving motion from side to side, in order to adjust the foci. This being done in such a manner that the circle of light of each lantern falls precisely upon the same spot upon the screen, the screws are tightened to the utmost extent so as to remove all possibility of further movement. The dissolving apparatus consists of a circular tin plate japanned in black, along three parts of the circumference of which a crescented aperture runs, the interval between the horns of the crescent being occupied by a circular opening, covered by a screwed plate, removeable at pleasure. This plate is fixed to a horizontal wooden axis, at the other end of which is a handle, by which the plate can be caused to rotate. The axis of wood is supported by two pillars connected with a flat piece which is secured to the tray. This apparatus is placed between the lanterns in such a manner that the circular plate is in front of the tubes of both, while the handle projects behind the lanterns at the back. The plate can, therefore, be turned round by means of the handle, without difficulty, from behind. A peg of wood is fixed into the axis, so as to prevent its effecting more than half a revolution. The widest part of the crescentic opening in the plate is sufficient to admit all the rays of the lantern before which it happens to be placed. On the plate being slowly turned half round, by means of the handle behind, the opening narrows until it is altogether lost in one of the horns of the crescent. The light of that lantern is gradually cut off as the aperture diminishes, until it is at length wholly shaded under the moveable cover occupying the interval between the horns of this crescentic opening. In proportion as the light is cut off from one, it is let on from the other tube, in consequence of the gradually-increasing size of the crescent revolving before it, until at length the widest part of this opening in the plate is presented before the tube of the second lantern, the first being, as we have seen, shaded. This movement being reversed, the light is cut off from the second lantern, and again let on from the first, and so on alternately. Thus while the screen always presents the same circle of light, yet it is derived first from one lantern, then from the next.

When in use a slider is introduced into each lantern. The lantern before the mouth of which the widest part in the opening in the plate is placed, exhibits the painting on the screen, the light of the other lantern being then hid behind the cover. On turning the handle, this picture gradually becomes shaded, while the light from the second lantern streams through the widening opening. The effect on the screen is the melting away of the first picture, and the brilliant development of the second, the screen being at no instant left unoccupied by a picture.

The principle involved in this apparently complex, but in reality simple mechanism, is, merely the obscuration of one picture and the throwing of a second in the same place on the screen. And it may be accomplished in a great variety of ways. Thus by simply placing a flat piece of wood, somewhat like the letter Z, on a point in the centre, so that alternately one or the other of the pieces at the end should be raised or depressed before the lanterns, a dissolving scene is produced. Or, by fixing a moveable upright shade, which can be pushed alternately before one or the other of the lanterns, the same effect is produced.

There are many individuals whose sole occupation consists in painting the minute scenes or slides used for the phantasmagoria lanterns. The perfection to which these paintings are brought is surprising, There are two methods by which the sliders now employed are produced. In one of these, the outline and detail are entirely the work of the artist's pencil. For pictures representing landscapes, or wherever a spirited painting is required, this is the exclusive method employed. The colours are rendered transparent by being ground in Canada balsam and mixed with varnish. The other method is a transfer process. The outlines of the subject are engraved on copper-plates, and the impression is received from these on thin sheets of glue, and is then transferred to a plate of glass, the impression being burnt in the same manner as is effected in earthenware. Sliders produced in this way receive the distinctive name of copper-plate sliders. The subject is merely represented in outline, it being left to the artist to fill up with the necessary tints, &c. The advantages of this method for the production of paintings of a limited kind are obvious. Photography on glass is now very largely employed to obtain pictures for the magic lantern.

Beechy's Trinoptric Lantern, which has been long manufactured by Mr. Abrahams of Liverpool, is an improvement on the ordinary phantasmagoria. The Bridgman Triple Lantern has recently been introduced.

PHENAKITE. A silicate of glucina. The Siberian crystals are occasionally cut for jewellery, and resemble rock crystal.

PHENAMEINE. See ANILINE VIOLET.

PHENICINE, *Phenicienne*, or *Phenyl Brown*. A colouring-matter produced by the action of nitro-sulphuric acid on phenylic alcohol (carbolic acid). Phenicine is an amorphous powder of a brown colour. It is sparingly soluble in water, but it dissolves readily in alcohol, ether, and acetic acid, also in the alkaline solutions, and in lime-water. The solution in an alkaline fluid is of a fine violet-blue, but it is changed to brown by the least excess of acid. It appears to be a mixture of two colouring-matters, one yellow, and the other black. Phenicine dyes silk and wool, like the aniline colours, without the intervention of a mordant. If a piece of silk or wool is dyed with phenicine, it acquires a fine garnet-red colour, on immersion in a solution of chromate of copper acidulated with sulphuric acid. Cotton being previously mordanted with tannin or stannate of soda may be dyed with phenicine of a deep purple colour, on being immersed in hot chromate of potash. The colour is, however, changed by alkalis, and destroyed by soap. See Carbolic Acid.

PHENOL. See Carbolic Acid.

PHENOL BLUE. Under certain circumstances, phenol gives rise to the formation of a blue colouring-matter, which is used to a certain extent in dyeing. This substance is known in commerce by the name of *azuline*. See Carbolic Acid.

PHORMIUM TENAX. New Zealand flax. From a Report of the Flax Commission appointed to examine into the preparation and value of the New Zealand flax, we learn that one general method of manufacture is adopted in the colony. This method has been thus described:—

'The green leaves are stripped by revolving-rollers with projecting beaters, travelling at a high rate of speed, which crush the epidermis against a fixed plate, so set as to allow room for the fibre to remain intact. The fibre, thus freed from the leaf of the plant, is washed by various methods, put on the ground or on lines to dry and bleach, finished by an arm or barrel-scutch, and when baled is ready for the market. No material alterations in the manufacturing processes have been made; but a more skilled labour and enlarged experience have improved the general quality of the fibre, so that it is more eagerly competed for in the London market as approaching nearer the appearance of Manilla hemp, and is, in fact, capable, in the opinion of competent judges, of being so prepared as to surpass it. The chief improvement recently introduced is the wet-scutching, by which the fibre is cleaned and softened, although it has not always been commercially successful; for, whilst local purchasers were ready to give 3*l.* per ton extra for the flax, the loss of fibre, by formation of an excessive amount of tow, and the additional expense of labour, increased the cost from 6*l.* to 10*l.*, so that the new process was abandoned. But, notwithstanding this, the Commissioners strongly recommend it for further trial. The mills are chiefly worked by steam-power; and good streams of water are also essential for the effectual washing of the fibre, which, when carefully prepared and neatly baled, fetches as much as from 17*l.* to 21*l.* per ton, although the ordinary price is about 15*l.* The cutting of the flax-leaves is an important point. In some fields an established vigorous plant, in suitable soil, will yield four good leaves for manufacture every year. The leaves are usually of twelve months' growth, and vary from 3 to 5 feet long. In some parts they are greatly injured by a small 'looper' caterpillar, about an inch in length, which eats quite through the fibre, in patches from ½ an inch to 2 inches long, and ¼ of an inch broad. This insect comes to its full size, and is most numerous, in the month of December. Of the leaves, when cut, 5½ tons yield one ton of fibre. They are mostly found after two years' growth to have passed their prime and begun to decay. The green strippings of the leaf form food for horses.'

The phormium fibre is largely used for rope-making. It is said that the New Zealand white rope when kept dry, lasts longer and wears 60 per cent. better than tarred rope of this material, and 34 per cent. better than Manilla-hemp fibre, but the effect of wetting with salt water acts injuriously upon the New Zealand rope, whilst the Manilla rope is said to be actually improved by the salting. The breaking-strain of Manilla-hemp rope being taken as 100, that of several varieties of New Zealand rope as at present exported varies from 53 to 84, with an average of 91. But samples of native-dressed New Zealand fibre ranged from 70 to 122, with an average of 91. During the year 1870 there were 161 mills in operation in the colony, with an aggregate of 342 stripping machines, employing 1,450 horse-power and 1,766 persons, and producing 4,457 tons of fibre. From April 1870 to May 1871, 36,008 bales of fibre were brought to London, in addition to which 87 were destroyed at sea; 1,546 bales of tow were also produced. The total value of the fibre, reckoning 6 bales to 1 ton, amounted to 140,506*l.*, the average price being 23*l.* 8*s.* per bale. See Fibres; Flax.

PHOSGENITE. Native chloro-carbonate of lead. See Lead.

PHOSPHATES. Combinations of phosphoric acid with metallic, earthy, or alkaline bases. A few only of these require notice in this work; all will be found described in Watts's 'Dictionary of Chemistry.'

Phosphate of Lime, or Acid Phosphate of Lime, is formed when bone-earth is treated with sulphuric acid. If bone-earth is digested with this acid for some time, and then water added, the clear solution filtered from the insoluble sulphate of lime will on evaporation yield crystals of phosphate of lime. Ground bones are frequently employed as a manure: their action depends in part upon the decomposed gelatine, but chiefly on the phosphate of lime, which they contain in the condition of a tribasic-phosphate. When, as for turnip-crops, a large supply of phosphoric acid is required, it is found advantageous to treat the bones with sulphuric acid, by which the triphosphate is converted into the acid phosphate of lime. The usual practice is to mix bone-dust with one-fourth of its weight of oil of vitriol, adding an equal quantity of water after each portion of acid; the mass is allowed to remain in a heap until quite dry. It is then sold as *superphosphate*, which is a mixture of the gelatinous portion of the bone with the acid phosphate and sulphate of lime. See APATITE; BONES; COPROLITE.

Phosphate of Magnesia enters into the composition of the bones of animals.

Amongst the native phosphates may be enumerated:—

Apatite. Phosphate of lime, the composition of which mineral is generally, phosphoric acid, 42·26; lime, 50·00; fluorine, 3·77. See APATITE.

Wagnerite. Phosphate of magnesia, with fluoride of magnesium.

Zwieselite. Phosphate of iron and manganese. See IRON.

Pyromorphite. Phosphate of lead. See LEAD.

Lazulite. Blue spar. See LAZULITE.

Turquoise. See TURQUOISE.

Vivianite. Blue iron earth or phosphate of iron. See IRON.

Libethenite. Phosphate of copper. See COPPER.

Ehlite. A hydrous phosphate of copper.

Wavellite. Sub-phosphate of alumina.

Childrenite, consists of phosphoric acid, 27·8; alumina, 14·4; protoxide of iron, 31·3; protoxite of manganese, 8·9; water, 17·6.

Phosphochalcite. Hydrous phosphate of copper.

Dufrenite. Green iron ore. Phosphoric acid, 28·0; peroxide of iron, 63·1; water, 8·9.

Uranite. Two varieties of this mineral are recognised: the one is a *copper-uranite*, known as *Torbnerite*, and consisting of a phosphate of uranium and copper; the other is a *lime-uranite*, known as *Autunite*, and composed of phosphate of uranium and lime.

Cryptolite. Phosphate of cerium.

Xenotime. Phosphate of yttria.

There are some other combinations which it is unnecessary to describe.

PHOSPHATIC NODULES. Concretions and nodules of phosphate of lime, which occur in layers chiefly in the Gault and Upper Greensand, and also in the Crag. They are now much used for artificial manure. See COPROLITES.

PHOSPHOR-BRONZE. Although the combination of phosphorus with copper, tin, zinc, and other alloys, dates a good way back, it is but yesterday since anything like a careful and skilful investigation of the physical properties of these combinations was undertaken.

The latest and most important of the experimental data as to the physical constants of phosphor-bronze which have been obtained are the following:—

Prussian Experiments.—By order of the Royal Prussian Ministry of Commerce experiments have been made with various sorts of phosphor-bronze. These experiments are carried on at the Royal Academy of Industry at Berlin. The object of these experiments is to ascertain the qualities and capacities of the metal whilst under heavy strain, and especially the comparative resistance to often-repeated strains, whether tensile or inflecting. The first bar of phosphor-bronze fixed on the stretching machine was tried under a constant strain of 10 tons per square inch, and resisted 408,230 pulls of this amount. A bar of ordinary bronze broke even before the strain of 10 tons per square inch had been attained. A second bar of phosphor-bronze was tried under a strain of 12½ tons per square inch; and under this high strain withstood 147,850 pulls. Yet more favourable results have been obtained on a machine by which the test-bar is repeatedly bent up to 40,000 times per day. A bar of phosphor-bronze whilst under 10 tons of strain per square inch resisted 862,980 bends, while best gun-metal broke after 102,650 bends. Another bar of phosphor-bronze under 9 tons strain per square inch is being tested, and has at present resisted 1,260,000 bends.

Austrian Experiments.—At the Imperial Austrian Polytechnic Institution in Vienna, experiments were executed by Professor R. Jenney with phosphor-bronze bars, showing the following results:—

Degree of elasticity	Resistance at point of elasticity	Resistance at point of rupture
9875	13·74 kilos. per sq. millimeter or 10,857 lbs. per square inch	40·40 kilos. per sq. millimeter or 58,383 lbs. per square inch

In the Imperial Arsenal at Vienna, experiments were made by Colonel Uchatius, giving the following results:—

	Absolute resistance	Point of elasticity	Stretch in percentage
			per cent.
Phosphor-bronze	5,660 kilos. per sq. c. m. or 81,795 lbs. per sq. inch	3,800 kilos. per sq. c. m. or 54,915 lbs. per sq. inch	1·6
Krupp's cast steel as used for guns	5,000 kilos. per sq. c. m. or 72,258 lbs. per sq. inch	1,000 kilos. per sq. c. m. or 14,450 lbs. per sq. inch	11·0
Ordnance bronze	2,200 kilos. per sq. c. m. or 31,792 lbs. per sq. inch	385 kilos. per sq. c. m. or 5,562 lbs. per sq. inch	15·0

Experiments on the capacity of phosphor-bronze to resist the oxidation of sea-water: Best English copper-sheets lost during six months immersion in sea-water 3·058 per cent. Phosphor-bronze sheets lost only 1·158 per cent.

To these may be subjoined the following results obtained by Messrs. Montefiore:—

Belgian Experiment.—Ordinary bronze always contains a larger or smaller amount of oxide in suspension. This has been contested by various authorities, as it was not possible to prove the presence of oxide of tin in the bronze by analysis, the oxide not being reduced by hydrogen at the temperatures which can be produced in laboratories.

By a longer series of experiments Messrs. Montefiore and Küntzel have now definitely proved the presence of oxide of tin and sub-oxide of copper. The presence of oxide greatly lessens the tenacity, elasticity, and tensile strength of the bronze. Various experiments were made in this direction. They melted shavings of old bronze and cast a bar thereof at 1,525° Cent. The remaining liquid bronze was stirred with a wooden stick (poled) and a second bar cast at 1,668° Cent. The remaining metal was deoxidised with phosphorus and a bar then cast at 1,614°. Then three castings were thus made out of the same crucible and in the same manner into three iron moulds. The results were as follow:—

Nature of the bronze	Absolute resistance	Elastic resistance	Lengthening until rupture	Diminution of section
			per cent.	per cent.
Old bronze . . .	1613	1209	2	3·2
" poled . .	1755	1244	2·8	3·2
" deoxidised " with phosphorus	2384	1356	6·8	6·7

Thus by the entire reduction the old bronze has tripled its tenacity and considerably augmented its absolute resistance.

Messrs. Alex. Dick and Co. have very recently established at Blackfriars Road London, a special foundry for phosphor-bronze casting, and have also made arrangements in Birmingham for the production of sheets, wire, &c.

The Table on p. 556 shows the results of Experiments to ascertain the Tensile Strength and the Resistance to Torsion of various Wires received from A. Dick, Esq., and made by Mr. David Kircaldy, of the testing and experimental works in Southwark.

PHOSPHORIC ACID exists abundantly in the mineral kingdom: it is found in several of the igneous rocks, in combination chiefly with lime. In the vegetable kingdom, it is discovered in the ashes of many plants, and it forms a large and important portion of the animal kingdom. *Anhydrous phosphoric acid*, is the acid formed by the vivid combustion of phosphorus. *Monabasic* or *metaphosphoric acid*, commonly known as glacial phosphoric acid, is now much employed in England, though for some time it did not attract the attention which it deserves in the arts and manufactures of this country. For many of the wants of the dyer, the calico-printer, the enameller, and even in the purification of some oils and fat, the glacial phosphoric acid has much to recommend it over any of the common acids at present in use. Nor need its price prove an obstacle to its introduction as a practical agent. Finely ground bone-ash, digested with a due proportion of oxalic acid and water, readily yields a solution of phosphoric acid, which requires only to be evaporated in a proper vessel to furnish at once this useful article. (*Ure.*) Unlike sulphuric and other strong acids, it is not decomposed by organic matter; and might hence be employed with great advantage in the precipitation of carmine and other delicate vegetable colours, as well as for

Description	Pulling stress. Wires as drawn					Twists in 5 in.				Pulling stress. Larger sized wire, annealed					
				Stress		As drawn		Annealed					Stress		Ultimate extension in 10 in.
	Test No.	Diam.	Area	Total	Per sq. in.	Test No.	Mean of three	Test No.	Mean of three	Test No.	Diam.	Area	Total	Per sq. in.	
	G.	inches	sq. in.	lbs.	lbs.	G.	twists	G.	twists	G.	inches	sq. in.	lbs.	lbs.	per cent.
Phosphorised bronze, No. 1	3600	·0665	·003472	339	97,638	3601	13·7	3749	81	3910	·1120	·00985	485	49,239	37·6
" " " 2	3602	·0655	·003367	340	100,980	3603	5·0	3750	91	3911	·1100	·00950	468	49,263	33·0
" " " 3	3604	·0655	·003367	346	102,759	3605	6·7	3751	87	3912	·1085	·00924	456	49,351	37·5
" " " 4	3606	·0640	·003216	389	120,957	3607	22·3	3752	52	3913	·1125	·00994	475	47,787	34·1
" " " 7	3608	·0605	·002871	306	106,583	3609	8·7	3753	106	3914	·1070	·00899	449	49,944	41·2
" " " 70	3610	·0630	·003116	322	103,337	3611	8·8	3754	93	...	...	...	...	...	...
" " " 8	3612	·0655	·003367	363	107,811	3613	5·8	3755	74	3915	·1085	·00924	488	52,814	33·9
" " " 90	3614	·0600	·002827	352	124,313	3615	7·0	3756	87	3916	·1070	·00899	480	53,392	34·2
" " " 10	3616	·0610	·002922	379	129,705	3617	8·3	3757	98	3917	·1105	·00959	485	50,573	41·5
" " " 13	3618	·0595	·002778	336	120,950	3619	13·0	3758	124	3918	·1115	·00976	521	53,381	42·4
" " " 14	3620	·0630	·003116	413	132,541	3621	3·0	3759	99	3919	·1115	·00976	578	59,221	38·5
" " " 15	3622	·0630	·003116	386	123,877	3623	3·7	3760	87	3920	·1110	·00967	586	60,599	39·3
" " " 16	3624	·0585	·002685	395	147,113	3625	7·5	3761	97	3921	·1105	·00959	540	56,309	35·1
" " " 17	3626	·0660	·003421	476	139,141	3627	17·3	3762	53	3922	·1140	·01020	555	54,411	44·9
" " " 20	3628	·0635	·003165	397	125,434	3629	4·5	3763	97	3923	·1125	·00994	528	53,119	36·3
" " " 21	3630	·0640	·003216	463	143,967	3631	13·5	3764	99	3924	·1120	·00985	570	57,869	43·0
" " " 22	3632	·0595	·002778	402	144,708	3633	4·5	3765	87	3925	·1120	·00985	578	88,680	33·9
" " " 23	3634	·0640	·003216	513	159,515	3635	13·3	3766	66	3926	·1125	·00994	585	58,853	46·6
" " " 25	3636	·0640	·003216	486	151,119	3637	15·8	3767	60	3927	·1120	·00985	636	64,569	42·8
" " " 26	3638	·0640	·003216	479	148,942	3639	15·9	3768	62	3928	·1090	·00933	557	59,700	46·1
Copper	3640	·0640	·003216	203	63,122	3641	86·7	3769	96	3929	·0640	·00321	119	37,002	34·1
Brass	3642	·0605	·002871	233	81,156	3643	14·7	3770	57	3930	·0605	·00287	148	51,550	36·5
Steel	3771	·0600	·002827	342	120,976	3772	22·4	3774	79	3773	·0600	·00282	211	74,637	10·9
Iron galvanised, best best C	3935	·0580	·002613	170	64,321	3936	26·0	3938	44	3937	·0580	·00264	162	61,294	17·1
" " " charcoal E	3939	·0580	·002643	174	65,834	3940	48·0	3942	87	3941	·0580	·00264	122	46,160	28·0

more general purposes. Some experiments have also shown that, combined with alumina and a little boracic acid, it is capable of producing a glaze for earthenware of extreme beauty and durability, in addition to its perfectly innocuous character and power of improving the colours imparted by most metallic oxides when applied to earthenware.

Another method of forming this monobasic acid is the following: one part of phosphorus is cut into small pieces, and introduced into a retort connected with a receiver, and containing thirteen parts of nitric acid, sp. gr. 1·2. The retort is moderately heated on a sand-bath, and the nitric acid which distils over returned to it from time to time until the phosphorus has disappeared. The greater part of the nitric acid is then distilled off, and the residual liquor evaporated so long as any water is evolved upon cooling: the phosphoric acid is a colourless glass, which dissolves slowly in water.

PHOSPHORITE. Concretionary and massive apatite. See APATITE.

PHOSPHORUS. (The following detailed description of the manufacture of phosphorus is left in Dr. Ure's own words, it being a good example of his descriptive powers when applied to scientific manufactures.) This interesting simple combustible being an object of extensive consumption, and therefore of a considerable chemical manufacture, I shall describe the requisite manipulations for preparing it at some detail. Put 1 cwt. of finely-ground bone-ash, such as is used by the assayers, into a stout tub, and let one person work it into a thin pap with twice its weight of water, and let him continue to stir it constantly with a wooden bar, while another person pours into it, in a uniform but very slender stream, 78 lbs. of concentrated sulphuric acid.

The heat thus excited in the dilution of the acid, and in its reaction upon the calcareous base, is favourable to the decomposition of the bone phosphate. Should the resulting sulphate of lime become lumpy, it must be reduced into a uniform paste, by the addition of a little water from time to time. This mixture must be made out of doors, as under an open shed, on account of the carbonic acid and other offensive gases which are extricated. At the end of 24 hours the pap may be thinned with water, and if convenient, heated, with careful stirring, to complete the chemical change, in a square pan made of sheet-lead, simply folded up at the sides. Whenever the paste has lost its granular character, it is ready for transfer into a series of tall casks, to be further diluted and settled, whereby the clear superphosphate of lime may be run off by a syphon from the deposit of gypsum. More water must then be mixed with the precipitate, after subsidence of which the supernatant liquor is again to be drawn off. The skilful operator employs the weak acid from one cask to wash the deposit in another, and thereby saves fuel and evaporation.

The collected liquors being put into a leaden, or preferably a copper pan, of proper dimensions, are to be concentrated by steady ebullition, till the calcareous deposit becomes considerable; after the whole has been allowed to cool, the clear liquor is to be run off, the sediment removed, and thrown on a filter. The evaporation of the clear liquor is to be urged till it acquires the consistence of honey. Being now weighed, it should amount to 37 pounds. One fourth of its weight of charcoal in fine powder, that is, about 9 pounds, is then to be incorporated with it, and the mixture is to be evaporated to dryness in a cast-iron pot. A good deal of sulphurous acid is disengaged along with the steam at first, from the reaction of the sulphuric acid upon the charcoal, and afterwards some sulphuretted hydrogen. When the mixture has become perfectly dry, as shown by the redness of the bottom of the pot, it is to be allowed to cool, and packed tight into stoneware jars, fitted with close covers, till it is to be subjected to distillation. For this purpose, earthen retorts of the best quality, and free from air-holes, must be taken, and evenly luted over the surface with a compost of fire-clay and horse-dung. When the coating is dry and sound, the retort is to be two-thirds filled with the powder, and placed upon proper supports in the laboratory of an air furnace, having its fire placed not immediately beneath the retort, but to one side, after the plan of a reverbatory; whereby the flame may play uniformly round the retort, and the fuel may be supplied as it is wanted, without admitting cold air to endanger its cracking. The gallery-furnace of the Palatinate (see MERCURY) will show how several retorts may be operated upon together, with one fire.

To the beak of the retort, properly inclined, the one end of a bent copper-tube is to be tightly luted, while the other end is plunged not more than one quarter of an inch beneath the surface of water contained in a small copper or tin trough placed beneath, close to the side of the furnace, or in a wide-mouthed bottle. It is of advantage to let the water be somewhat warm, in order to prevent the concretion of the phosphorus in the copper-tube, and the consequent obstruction of the passage. Should the beak of the retort appear to get filled with solid phosphorus, a bent rod of iron may be heated and passed up the copper-tube, without removing its end from the water. The heat of the furnace should be most slowly raised at first, but afterwards equably maintained in a state of bright ignition. After 3 or 4 hours of steady firing, carbonic acid and sulphurous acid gases are evolved in considerable abundance, provided the materials had not been well dried in the iron pot; then sulphuretted hydrogen makes its appearance, and next phosphuretted hydrogen, which last should continue during the whole of the distillation.

The firing should be regulated by the escape of this remarkable gas, which ought to be at the rate of about 2 bubbles per second. If the discharge comes to be interrupted, it is to be ascribed either to the temperature being too low, or to the retort getting cracked; and if upon raising the heat sufficiently no bubbles appear, it is a proof that the apparatus has become defective, and that it is needless to continue the operation. In fact, the great nicety in distilling phosphorus lies in the management of the fire, which must be incessantly watched, and fed by the successive introduction of fuel, consisting of coke with a mixture of dry wood and coal.

We may infer that the process approaches its conclusion by the increasing slowness with which gas is disengaged under a powerful heat; and when it ceases to come over, we may cease firing, taking care to prevent reflux of water into the retort, from condensation of its gaseous contents, by admitting air into it through a recurved glass tube or through the lute of the copper adapter.

The usual period of the operation upon the great scale is from 24 to 30 hours. Its theory is very obvious. The charcoal at an elevated temperature disoxygenates the phosphoric acid with the production of carbonic acid gas at first, and afterwards carbonic oxide gas, along with sulphuretted, carburetted, and phosphuretted hydrogen, from the reaction of the water present in the charcoal upon the other ingredients.

The phosphorus falls down in drops, like melted wax, and concretes at the bottom of the water in the receiver. It requires to be purified by squeezing in a shamoy leather bag, while immersed under the surface of warm water, contained in an earthen pan. Each bag must be firmly tied into a ball form, of the size of the fist, and compressed under the water heated to 130°, by a pair of flat wooden pincers, like those with which oranges are squeezed.

The purified phosphorus is moulded for sale into little cylinders, by melting it at the bottom of a deep jar filled with water, then plunging the wider end of a slightly tapering but straight glass tube into the water, sucking this up to the top of the glass, so as to warm it, next immersing the end in the liquid phosphorus, and sucking it up to any desired height.

The tube being now shut at bottom by the application of the point of the left index, may be taken from the mouth and transferred into a pan of cold water to congeal the phosphorus; which then will commonly fall out of itself, if the tube be nicely tapered, or may at any rate be pushed out with a stiff wire. Were the glass tube not duly warmed before sucking up the phosphorus, this would be apt to congeal at the sides before the middle be filled, and thus form hollow cylinders, very troublesome and even dangerous to the makers of phosphoric match-bottles. The moulded sticks of phosphorus are finally to be cut with scissors under water to the requisite lengths, and put up in phials of a proper size; which should be filled up with water, closed with ground stoppers, and kept in a dark place. For carriage to a distance, each vial should be wrapped in paper, and fitted into a tin-plate case.

Phosphorus has a pale yellow colour, is nearly transparent, brittle when cold, soft and pliable, like wax, at the temperature of 70° F., crystallising in rhombo-dodecahedrons out of its combination with sulphur, and of specific gravity 1·77. It exhales white fumes in the air, which have a garlic smell, appear luminous in the dark, and spontaneously condense into liquid phosphorus acid. Phosphorus melts in close vessels, at 95° F., into an oily-looking colourless fluid; begins to evaporate at 217·5°, boils at 554°, and if poured in the liquid state into ice-cold water, it becomes black, but resumes its former colour when again melted and slowly cooled. It has an acrid disagreeable taste, and acts deleteriously in the stomach, though it has been administered as a medicine by some of the poison-doctors of the present day. It takes fire in the open air at the temperature of 165°, but at a lower degree if partially oxidised, and burns with great vehemence and splendour.

PHOSPHORUS, AMORPHOUS, or **RED PHOSPHORUS.** If a stick of phosphorus be put into an hermetically-closed tube and exposed to the action of the spectrum, one end will become *white*, and the other *red*. It may be prepared also by exposing phosphorus for a long time in an atmosphere quite free of oxygen or moisture, to a temperature of 470° F. At this temperature the phosphorus fuses; it remains for some time colourless, and then gradually becomes red and opaque. Amorphous phosphorus was investigated by Dr. Schrötter, of Vienna. The apparatus for making it consists of a double iron pan; the intermediate space between the two contains a metallic bath of an alloy of tin and lead; with a cast-iron cover to the inner vessel, fitted to the top end by means of a screw, and fastened to the outer vessel by screw-pins. In the interior iron pan a glass vessel is fitted, in which the phosphorus to be operated upon is placed. From this inner vessel a tube passes, and is dipped into water to serve as a safety-valve. A spirit lamp is applied under that pipe if necessary, to prevent it being clogged with phosphorus. The phosphorus to be converted is first of all melted, and then cooled under water, and dried as much as possible. A fire is now made under the other vessel, and the temperature raised to such a degree as to drive off the air, &c. The temperature has to be gradually raised, until bubbles escape at the end of the pipe, which take fire as they enter the air, and the heat may soon rise in the bath till it be 470° F. This temperature must be maintained for a certain time to be determined by experience: the apparatus may then be allowed to cool. The converted phosphorus is difficult to detach from the glass. It is to be levigated under water, and then drained in a bag. The phosphorus when moist should be spread thinly on separate shallow trays of sheet iron or lead, so placed alongside each other as to receive the heat of steam, and lastly, of chloride of calcium, or of sand, till the phosphorus, having been frequently stirred, shows no more luminous vapour. The operator should have water at hand to quench any fire that might arise. It is then to be washed till the water shows no trace of acid. Should the resulting phosphorus contain some of the unconverted article, this may be removed by bisulphide of carbon. Thus, heat alone effects the transmutation. It is identical in composition with ordinary phosphorus, and may be reconverted into it without loss of weight, and that merely by change of temperature. This substance remains unaltered in the atmosphere, is insoluble in bisulphide of carbon, in alcohol, ether, and naphtha. It requires a heat of 260° Cent. to restore it to the ordinary state, and it is only at that heat that it begins to take fire in the open air. It is not luminous in the dark at any ordinary temperature. When perfectly dry, amorphous phosphorus is a scarlet or carmine powder, which becomes darker when heated. On the large scale it is prepared in dark masses of a red or dark brown colour. The great advantages of this singular condition of phosphorus are, that it does not appear to affect those persons who are employed in the manufacture of lucifer-matches with the loathsome disease which the use of the ordinary phosphorus produces. See LUCIFER-MATCHES.

PHOSPHORUS MATCHES. See LUCIFER-MATCHES.

PHOSPHORUS PASTE, *for the Destruction of Rats and Mice.* The Prussian Government issued an ordonnance on April 27, 1843, directing the following composition to be substituted for arsenic, for destroying rats and mice; enjoining the authorities of the different provinces to communicate, at the expiration of a year, the results of the trials made with it, with the view of framing a law on this subject.

The following is the formula for this paste:—

Take of phosphorus 8 parts, liquefy it in 180 parts of lukewarm water; pour the whole into a mortar, add immediately 180 parts of rye-meal; when cold, mix in 180 parts of butter melted, and 125 parts of sugar. If the phosphorus is in a finely-divided state, the ingredients may be all mixed at once without melting them. This mixture will retain its efficacy for many years, for the phosphorus is preserved by the butter, and only becomes oxidised on the surface. Rats and mice eat this mixture with avidity; after which they swell out, and soon die. Several similar preparations are now made in this country for the destruction of vermin.

PHOTO-GALVANOGRAPHY. A name given to a process invented by Mr. Pretsch, for producing engravings from photographs, by the application of the *galvano-plastic* process. It is not now employed, although great efforts were made to introduce it to the public. The principles involved are sufficiently described in the article on PHOTOGRAPHIC ENGRAVING.

PHOTOGEN. Syn. *Paraffin Oil.* A term which has recently found its way into commerce, to designate certain oils or naphthas for illuminating purposes. It is generally prepared from shales, brown coals, or cannels. Boghead coal, and the numerous varieties of inflammable shales which more or less resemble it, are specially adapted for the preparation of photogen. The chief physical difference between photogen and ordinary coal-oils of the same boiling-point, is the specific gravity, with which the former varies from 0·820 to 0·830, whereas common coal-naphtha never has a less density than 0·850. It is true that photogen may be obtained of as high a density as 0·900, but then it will be of an excessively high boiling-point, and, in all probability, saturated with paraffin.

The light oil known as photogen may be obtained from common bituminous coals by distilling them at a lower temperature than is employed in gas-works. To obtain the maximum amount of photogen from coal, the temperature should not be much above 700° Cent.

Preparation.—The coals, broken into small pieces (the smaller the better), are to be heated in vertical or horizontal iron retorts, the tar being received through a very wide worm into large tanks. Some manufacturers use vertical, and others horizontal retorts; it is also common to distil the coals by the heat produced by their own combustion. If the latter process be employed, the arrangements for condensing the product must be very perfect, or great loss will be sustained, owing to the air which supports the combustion carrying away a considerable quantity of the hydrocarbons. This power of air to saturate itself with vapours is of great importance in the economy of all processes where the distillation of one portion of substance is carried on by the heat evolved by the combustion of another. It is not uncommon in practice, where the cylinders are horizontal, to place the coal or other matters to be distilled in semicylindrical trays, which are capable of being inserted into the retorts, and also of being removed to make way for another charge at the completion of the operation.

The tar obtained by any of the above processes is to be redistilled: the lighter portions form (when purified by means of sulphuric acid and alkalis) the fluid known in commerce as 'Boghead naphtha.' (See NAPHTHA, BOGHEAD.) In Germany and some other places, it is usual to divide the distillate from the tar into two portions, one being for the preparation of photogen, and the other for 'solar oil.' This division is made as the fluid runs from the still; the more volatile constituting the photogen, and the less the solar oil.

The process of purification is the same in both cases, namely, alternate treatments with concentrated sulphuric acid to remove the highly-coloured and odorous constituents of the crude distillate, and washing with an alkali to remove carbolic acid and its congeners; also that portion of sulphuric acid which remains suspended in the naphtha, and the sulphurous acid produced by the decomposition of a portion of the sulphuric acid by the carbon of certain easily-decomposed organic matters in the crude distillate. This decomposition of the sulphuric acid happens thus:—

$$2SO^3HO + C = 2SO^2 + 2HO + CO^2$$
$$(\mathbf{2H^2SO^4 + C = 2SO^2 + 2H^2O + CO^2}).$$

There is another advantage in the treatment of the fluid by alkalis, inasmuch as some sulphide of hydrogen, and probably other fœtid sulphur-compounds, is decomposed and the resulting products removed.

In preparing photogen from any of the sources enumerated, much must be left to the discretion of the manufacturer, both as regards the apparatus and the chemical processes. In some instances the solar oil and photogen are with advantage prepared separately; but in this country it is more usual to mix the heavy and light oils together, so as to produce a fluid of medium density and volatility. It must be remembered that while the more volatile hydrocarbons confer extreme inflammability and fluidity, they are at the same time more odorous than the less volatile portion of the distillate, which is the true paraffin oil.

The more odorous impurities in photogen appear to be easily susceptible of oxidation. This is evident from the facility with which foully-smelling photogen loses its offensive odour in contact with bichromate or manganate of potash, or even animal charcoal. Their exposure to air even greatly improves the odour, and a recently-distilled photogen, which is very unpleasant, becomes comparatively sweet if kept in tanks or barrels for a few days. The same thing happens with many essential oils, such as those of peppermint, cloves, &c. The presence of sulphurous acid in photogen may be instantly detected by shaking a little in a test-tube with a few drops of a very weak solution of bichromate of potash; if sulphurous acid be present, a portion of the chromic acid will be reduced to green oxide, which will instantly betray the presence of the reducing agent alluded to.

Photogen often shows the phenomenon of dichroism; but the more it is purified by acids, the more feebly is the coloration by reflected light observed, and if the less volatile portion of the distillate be rejected, the property alluded to will not be perceived.

In distilling the heavy oils or tars produced by distilling Boghead coal or other photogen-yielding substances, it is particularly to be observed that the worms or other tubes proceeding from the stills, if of too small diameter, are liable to become choked up with paraffin; this, if unobserved, might lead to serious results. It is very convenient to have a steam-pipe inserted into the worm-tubes or condensing-tanks, to enable the water to be heated to such a point as to melt any solid matters in the worms, and allow them to be washed into the recipient by the fluids distilling over.

The following Table by Wagenmann will be found of great importance to those who are interested in the commercial value of the different varieties of coals and bitumens as sources of illuminating oils :—

Name	Locality	Tar per cent.	Specific gravity	Crude oil sp. gr. from 0·700 to 0·950	Crude oil sp. gr. from 0·850 to 0·900	Crude paraffin
Trinidad Pitch .	Trinidad	70	·875	40	20	1⅓
Boghead coal .	Scotland	33	·860	12	18	1¼
Torbane mineral .	„	31	·861	11	16	1¼
Dorset shale . .	England	9	·910	1	6	1/30
Rangoon naphtha .	Burmah	80	·870	50	20	3
Belmar turf . .	Ireland	3	·920	1	1	⅙
George's bitumen .	Neuwied	29	·865	8¼	14	1¾
Paper coal, No. 1 .	Siebengebirge	20	·880	6	9	¾
„ No. 2 .	„	15	·880	5	7	½
„ No. 3 .	„	11	·880	3	6	⅓
„ „ .	Hesse	25	·880	6	12	1
„ „ .	Rhenish Provinces	11	·880	3	5	½
„ „ .	Bonn	4	·930	1/10	3	¼
Brown coal . .	Saxony (Province)	7	·910	2	3	½
„ . .	Saxony (Kingdom)	10	·920	2	4	¾
„ . .	„ „	6	·915	½	4	½
„ . .	„ „	5	·910	⅓	3½	¼
„ . .	„ „	6	·910	¾	4½	⅓
„ . .	„ „	9½	·920	2	5	1
„ . .	„ „	6	·910	1	4	½
„ . .	„ „	4	·910	1	2	⅓
„ . .	„ „	9½	·920	2	5	⅔
„ . .	Thuringia	5	·918	1½	1	¾
„ . .	„	5	·920	¼	3½	¼
„ . .	Neuwied	5½	·920	1	5	½
„ . .	Bohemia	11	·860	3	5	¾
„ . .	Westerwald	5½	·910	1½	1½	
„ . .	„	3½	·910	1	1	
„ . .	Nassau	4	·910	2	1½	
„ . .	„	3	·910	1	1	
„ . .	Frankfort	9	·890	2	6	

None of the cannel or bituminous coal, shales, or other substances used for yielding burning fluids by distillation, give distillates of such purity and freedom from odour, as Rangoon tar. The more volatile portion of the distillate from the latter has obtained in commerce the absurd name of Sherwoodole; it is used instead of coal-benzole for removing grease, &c. The paraffin obtained from Rangoon tar has a greater value for commercial purposes than that from Boghead coal, inasmuch as it has a higher melting-point, which renders it better adapted for candles. The following are the melting-points of various samples of paraffin :—

	Melting-point. Fahr.
Boghead-coal paraffin	114°
„ „ another specimen	108
The last, after being distilled	108
Turf paraffin	116
Bituminous-coal paraffin, prepared by Atwood's process .	110
Rangoon-tar paraffin	140

It is curious to observe the effect of light upon photogen. Some samples of extremely dark colour, when exposed to its influence for a few days, become as completely bleached as animal oils would under these circumstances. At the same time, as we have before hinted, the odour becomes much improved. A photogen of good quality has by no means a repulsive odour, but if much of the more volatile constituents be present, it is impossible to avoid its being disagreeable if spilled about. The less volatile hydrocarbons have comparatively little odour. It should not be too inflammable, that is to say, it must not take fire on the approach of a light. If it does, it is owing to the more volatile portion not having been sufficiently removed. See Paraffin for a description of its manufacture.

PHOTOGRAPHIC ENGRAVING. The first who appears to have had any idea of engraving by the influence of sunlight was Nicephore Nièpce. According to M. Aimé Girard, the first proof taken by him by means of this process bears date 1827. This process was very simple: it consisted in spreading a thin layer of bitumen of Judæa upon a copper- or pewter-plate, which was then placed in the camera obscura, where it was allowed to remain some hours, until the bitumen had received the impression of the external objects towards which the lens had been directed. On withdrawing the plate, it was submitted to the action of the essential oil of lavender, which dissolved those portions of the bitumen not acted upon by the light, leaving the metal bare, while the remaining bitumen produced the design. Passing the plate afterwards through an acid solution, the acid acted on the metallic plate, while the other parts were preserved by the protecting varnish.

Six years later, that is, in 1839, M. Daguerre made his discovery of the 'Daguerreotype' public. In the meantime, he had considerably improved on Nièpce's process; but although many, and some tolerably successful, attempts were made to engrave the pictures produced by these processes, none were quite successful.

The next process to which we shall refer is that of M. Fizeau. He took a Daguerreotype plate, and submitted it to the action of a mixture of nitric, nitrous, and hydrochloric acids, which did not affect the whites of the picture but attacked the blacks with a resulting formation of adherent chloride of silver, which speedily arrested the action of the acid. This he removed by a solution of ammonia, and the action of the acid was continued. This process he continued until a finely-engraved plate was the result; but the lines of this plate were not deep enough to allow of many prints being taken from it. To remedy this, he covered the plate with some drying oil, and then, wiping it from the surface, left it to dry in the hollows. He afterwards submitted the plate to an electro-chemical process which covered the raised parts with gold, leaving the hollows, in which the varnish remained, untouched. On the completion of the gilding, the varnish was removed by means of caustic potash, and the surface of the plate, covered with *grains de gravure*, producing what is technically termed an *aquatint* ground, and the deepening of the lines was proceeded with by means of the acid. The Daguerreotype plate was by these means converted into an engraved plate, but as it was silver it would have worn out very soon; to obviate which an impression was taken on copper by the electro-chemical process, which could of course be renewed when it showed signs of wear.

M. Claudet and Mr. Grove both produced some very good engravings on the Daguerreotype plate, but these processes have proved rather curious than useful.

On October 29, 1852, Mr. Fox Talbot patented a process, which was similar to a process previously used by MM. Pretsch and Poitevin, as regards the substance first employed, viz. a mixture of bichromate of potash and gelatine; but the remaining portion of the process was conducted on the same principle, though in a different manner, to that of M. Fizeau.

Mr. Mungo Ponton discovered the use of the bichromate of potash as a photographic agent; and Mr. Robert Hunt subsequently published a process, called the 'Chromotype.' In both these processes the peculiar property of the chromic acid, liberated under the action of sunshine, to combine with organic matter, was pointed out. MM. Pretsch, Poitevin, and Talbot, only availed themselves of this previous discovery, and in each instance gelatine was rendered insoluble by the decomposition of the bichromate of potash under the influence of *actinic* power. By dissolving off the still soluble portions of the gelatine, either metal could be precipitated by the voltaic battery, or an etching produced.

In 1853 M. Nièpce de St. Victor, the nephew of Nicephore Nièpce, took up his uncle's plan, and with the assistance of M. Lemaitre, who had also assisted his uncle, endeavoured to perfect it; but, though he modified and improved it, his success was not very great—it was always found necessary to have the assistance of an engraver to complete the plate.

After this many others, among whom may be enumerated MM. Lerebours, Lemercier, Barreswil, Davanne, and, finally, Poitevin, endeavoured to obtain a design by similar means on stone. The last appears to have succeeded. His method is based on the chemical action of light on a mixture of gelatine and bichromate of potash, as above. This mixture, which when made is perfectly soluble in water, becomes insoluble after exposure to the light. His mode of proceeding is as follows:—

He spreads the mixture on the stone, and, after drying, lays the negative upon it, and exposes it to the light. After a suitable exposure the negative is removed, and the portions not acted upon by the light are washed away with water, and the design remains with the property of taking the ink like an ordinary lithographic crayon. The stone is then transferred to the press, and proofs taken in the usual way. It is said that pictures have been obtained from the stone after 900 copies had been pulled.

The process of M. Charles Négre was more complicated than the preceding, but yielded superior results. His process was not unlike that of M. Fizeau.

Mr. Fox Talbot thus describes his process of *Photoglyphic Engraving*:—

'I employ plates of steel, copper, or zinc, such as are commonly used by engravers. Before using a plate its surface should be well cleaned; it should then be rubbed with a linen cloth dipped in a mixture of caustic soda and whiting, in order to remove any remaining trace of greasiness. The plate is then to be rubbed dry with another linen cloth. This process is then to be repeated; after which, the plate is in general sufficiently clean.

'In order to engrave a plate, I first cover it with a substance which is sensitive to light. This is prepared as follows:—

'About a quarter of an ounce of gelatine is dissolved in eight or ten ounces of water, by the aid of heat. To this solution is added about one ounce, by measure, of a saturated solution of bichromate of potash in water, and the mixture is strained through a linen cloth. The best sort of gelatine for the purpose is that used by cooks and confectioners; in default of this, isinglass may be used, but it does not answer so well. This mixture of gelatine and bichromate of potash keeps good for several months, owing to the antiseptic and preserving power of the bichromate. It remains liquid and ready for use at any time during the summer months; but in cold weather it becomes a jelly, and has to be warmed before using it: it should be kept in a cupboard or dark place. The proportions given above are convenient, but they may be considerably varied without injuring the result.

'The engraving process should be carried on in a partially-darkened room, and is performed as follows:—

'A little of this prepared gelatine is poured on the plate to be engraved, which is then held vertical, and the superfluous liquid allowed to drain off at one of the corners of the plate. It is held in a horizontal position over a spirit-lamp, which soon dries the gelatine, which is left as a thin film, of a pale yellow colour, covering the metallic surface, and generally bordered with several narrow bands of prismatic colours. These colours are of use to the operator, by enabling him to judge of the thinness of the film: when it is very thin, the prismatic colours are seen over the whole surface of the plate. Such plates often make excellent engravings; nevertheless, it is perhaps safer to use gelatine films, which are a little thicker. Experience alone can guide the operator to the best result. The object to be engraved is then laid on the metal plate, and screwed down upon it in a photographic copying-frame. Such objects may be either material substances, as lace, the leaves of plants, &c., or they may be engravings, or writings, or photographs, &c. &c. The plate bearing the object upon it is then to be placed in the sunshine, for a space of time varying from one to several minutes, according to circumstances; or else it may be placed in common daylight, but of course for a long time. As in other photographic processes, the judgment of the operator is here called into play, and his experience guides him as to the proper time of exposure to the light. When the frame is withdrawn from the light, and the object removed from the plate, a faint image is seen upon it—the yellow colour of the gelatine having turned brown wherever the light has acted.

'When the plate bearing the photographic image is removed from the copying frame, I spread over its surface, carefully and very evenly, a little finely-powdered gum copal. It is much easier to spread this resinous powder evenly upon the surface of the gelatine, than it is to do so upon the naked surface of a metal plate. The chief error the operator has to guard against is that of putting on too much of the powder: the best results are obtained by using a very thin layer of it, provided it is uniformly distributed. If too much of the powder is laid on it, it impedes the action of the etching liquid. When the plate has been thus very thinly powdered with copal, it is held horizontally over a spirit-lamp in order to melt the copal; this requires a considerable heat. It might be supposed that this heating of the plate, after the formation of a delicate photographic image upon it, would disturb and injure that image; but it has no such effect. The melting of the copal is known by the change of colour, The plate should then be withdrawn from the lamp, and suffered to cool. This process may be called the laying an aquatint ground upon the gelatine, and I believe it to be a new process. In the common mode of laying an aquatint ground, the resinous particles are laid upon the naked surface of the metal, before the engraving is commenced. The gelatine being thus covered with a layer of copal, disseminated uniformly and in minute particles, the etching liquid is to be poured on. This is prepared as follows:—Muriatic acid, otherwise called hydrochloric acid, is saturated with per oxide of iron as much as it will dissolve with the aid of heat. After straining the solution, to remove impurities, it is evaporated till it is considerably reduced in volume, and is then poured off into bottles of a convenient capacity; as it cools, it solidifies into a brown semi-crystalline mass. The bottles are then well corked-up, and kept for use. I shall call this preparation of iron by the name of "perchloride of iron." It is a substance very attractive of moisture.

'Water dissolves an extraordinary quantity of it, sometimes evolving much heat during the solution. I find that the following is a convenient way of proceeding:—

'A bottle (No. 1) is filled with a saturated solution of perchloride of iron in water. A bottle (No. 2) with a mixture consisting of five or six parts of the saturated solution and one part of water. And a bottle (No. 3) with a weaker liquid, consisting of equal parts of water and the saturated solution. Before attempting an engraving of importance, it is almost essential to make preliminary trials, in order to ascertain that these liquids are of the proper strength. I have already explained how the photographic image is made on the surface of the gelatine, and covered with a thin layer of powdered copal or resin, which is then melted by holding the plate over a lamp. When the plate has become perfectly cold, it is ready for the etching process, which is performed as follows:—A small quantity of the solution in bottle No. 2, viz. that consisting of five or six parts of saturated solution to one of water, is poured upon the plate, and spread with a camel's-hair brush evenly all over it. It is not necessary to make a wall of wax round the plate, because the quantity of liquid employed is so small that it has no tendency to run off the plate. The liquid penetrates the gelatine wherever the light has not acted on it, but it refuses to penetrate those parts upon which the light has sufficiently acted. It is upon this remarkable fact that the art of photoglyphic engraving is mainly founded.'

Photographic engraving has not, up to the present time (1874), been successfully introduced into the arts. Many especially interesting processes have been devised; and on the small scale, with the proper amount of care, they have been all that is desirable; but, when it has been attempted to apply the process on the larger scale, it has either failed entirely, been uncertain in its results, or too costly for the general public.

PHOTOGRAPHIC PRINTING. Numerous experiments have been made for the purpose of preparing surfaces upon which pictures could be obtained by the action of sunshine, or on to which photographic pictures could be transferred.

Most of the processes are founded on the peculiar action of the solar rays upon the bichromate of potash dissolved in a solution of gelatine. It is not possible in a work of this class to do more than deal with the general principles involved. In the last edition, Woodbury's relief-printing was alone described. A portion of that description is retained.

The process is thus described:—A sheet of talc (mica) of the size required is affixed with gum or water to a plate of glass, and placed on a levelling stand; some bichromatised gelatine is then poured on its surface to form an even coating. When quite dry, the talc by means of a knife is removed, the exposed surface carefully cleaned, and placed in contact with the negative that is to be reproduced. The gelatine is protected by a piece of blotting-paper, then covered with a glass to ensure uniform pressure and close contact between the talc and the negative. After exposure to the sun for an hour, the film must be placed face upwards in a dish of hot water; this will dissolve all the gelatine unacted upon by the sun, leaving a picture in relief, the parts most acted on standing in highest relief. When no more gelatine will dissolve, the film is dried by heat to a certain stage, then naturally.

The metallic intaglio is produced in the following manner:—The gelatine relief, with a clean sheet of metal composed of type-metal and lead placed on it, is submitted to hydraulic pressure. As it is of the greatest importance that it should be kept perfectly flat, a sheet of steel of sufficient thickness to prevent its bending or yielding when in the press, is placed under the talc, and a similar one on top of the metal. The amount of pressure varies with the softness of the metal employed, but the approximate amount may be stated as 4 tons to the square inch. This process does not in the least injure the gelatine mould, which will serve many times.

The process of printing from the metal mould is conducted in the following manner:—The press is made in the form of a very shallow box with a winged lid. In the bottom of the box is placed a plate of thick glass (resting on four screws), and in the lid is a similar plate. The mould is placed face upwards on the glass in the box, and raised by means of the screws to come in contact with the glass lid when closed. A small quantity of ink is then placed on the middle of the mould, the sheet of paper is laid on the top of the ink, and the lid being closed, the ink spreads out between the paper and the mould, filling up the cavities in the latter, the superfluous portion escaping over the edges. The lid should remain closed until the ink is sufficiently set to allow of its being removed with the paper. The conditions required in the ink are fluidity with rapid setting, transparency, and facility for the removal from the mould with perfect adherence to the paper. All these are found in gelatine, to which any colouring-matter may be added. The ink must be kept warm, the heat and strength being such as to ensure its setting in a reasonable time; the mould should be slightly moistened with oil to prevent the ink adhering to it.

After remaining in the box for about a minute the paper is removed, taking with it the mass of gelatine, which at this stage forms a picture in relief (hence the name of this process, *relief-printing*), but as it dries, this peculiarity gradually disappears, and when it is quite dry not a trace of it is left. One operator may work several of these presses at the same time, and by so doing he may produce from 150 to 200 prints per hour. The print is fixed by immersing it for a short time in a solution of alum, which renders it impervious to moisture and improves its mechanical condition.

Mr. Walter Bentley Woodbury obtained two patents for modified forms of his process in 1870 and in 1872, for sundry improvements in the '*Woodbury Type*;' his latest process being the following one, quoted from the Specification of his process, dated December 4, 1872:—

'In place of using a thin film of collodion (as is generally used in the process called 'Woodbury type') to hold the gelatine of the relief, I proceed as follows:—I first rub over a sheet of plate-glass with French chalk or ox gall, and then coat with the bichromatised gelatine solution as now used. When this is dried and ready for use, I expose the side that was next to the glass for a few seconds to daylight before exposing it under the negative. This has the effect of causing a thin film of the gelatine to become insoluble, which after subsequent exposure under the negative will not wash away, but form a support for the photographic image afterwards impressed, thus doing away with the expense and trouble of the double coatings as now practised. When the gelatine relief is dried in the ordinary way I take a thin sheet of tin foil (same size as the gelatine relief), and attach it by gum or other adhesive substance around the edges to the gelatine relief. I now lay on the back of this a stout sheet of plate-paper, and pass the whole through an ordinary rolling press; the tin foil is by this means impressed into all the details of the relief, but in that state it would be useless to print from. I then proceed as follows:—A shallow metal box is filled with a composition of shellac and asphalt which on warming becomes soft, but hardens on cooling; this box is placed on a hot plate until the composition it contains softens; it is then placed on the lower plate of the ordinary Woodbury printing-press, the foil and relief laid on it, the press closed and the pressure applied by the under screw. When the composition has hardened the tin foil adheres to it, and I remove the gelatine relief from the foil, and use the foil-backed mould to print from. In place of fixing the proofs by alum or other substance of a like nature I varnish the proofs with an ordinary varnish composed of shellac and alcohol, which gives the print the effect of a photograph on albumenised paper, at the same time protecting the surface from moisture. I also sometimes use the composition above named without the foil as a printing-mould direct, and when sufficient numbers have been printed the box holding the composition is again heated, and can be used over and over again. The third part of my invention consists in an improved method of printing Woodbury type by machinery. This I accomplish as follows:—Out of a solid block of iron I have turned a cylindrical hole in which is made to fit very loosely a cylinder of soft metal, having a taper or conical hole through it lengthwise. Between the interior of the steel block and the soft metal cylinder I insert the gelatine reliefs, then by means of a taper or wedge-shaped spindle (roughened) I drive by hammering or by pressure the soft metal against the iron cylinder, thus impressing the relief on the outside of the metal cylinder, the taper spindle at the same time forming a shaft for the cylinder to be used in the process of printing. I then mount this roller bearing the relief in vertical slots in a frame having a bed of plate-glass on which the paper rests, the roller resting on the glass by its own weight and being dragged round by the paper itself, or in place of the glass plate I allow the soft metal to lie on another fixed or moveable roller of metal or glass. The latter may be hollow so as to reduce its temperature in hot weather by a stream of cold water running through it.'

Mr. Joseph Wilson Swan, of Newcastle, was a very zealous worker. He combined with the bichromated gelatine carbon or other colouring-matter. The intermediate stages of the process were as in other of the chromotype processes, and the coloured gelatine was made to receive a printing ink, and impressions were taken therefrom. In 1865 he improved his process as follows:—When the image is produced by means of a negative that is employed to produce an impression of the sensitive gelatinous tissue, previous to its development the tissue is mounted upon a surface of glass, and the uncoated surface of the glass is placed towards the light. Warm water is used to dissolve the soluble portions of the gelatinous coating, and thus to develop the image. The plate bearing this image is surrounded with a rim, hardened by means of a protosalt of iron or of sulphate of alumina. The surface is coated with silver while wet and electrotyped in copper, and from this plate with proper precautions any number of copies can be printed off. In 1872 Mr. Swan informed the writer that the process had been much improved, particularly in the transfer part of the process. The tissue, after being impressed by the solar action in the printing-frame, is now attached to the surface on which the development of the pictures is effected *without the aid of any cementing material*, and *without the employment of a press.* The natural adhesiveness of the tissue itself, aided as it is by atmospheric pressure and capillary attraction, obtains a very perfect attachment of the tissue to either a plate of glass or metal or to insoluble gelatinised or insoluble coagulated albumenised paper. In practice the tissue is transferred for development (by warm water) to a zinc plate *when it is required to be re-transferred to paper* (to procure reversal), and when the re-transfer is not required the tissue is at once transferred to (and the picture developed upon) paper faced with some insoluble material such as named, or lac. Mr. Johnson, who has latterly done much in the improvement of the process in connection with the points referred to, and who works in conjunction with the Autotype Company, prefers to use a paper faced with lac, decolourised of course. This process has been largely developed as the '*autotype process*' and many very fine productions are now being regularly published.

Numerous modifications of these processes have from time to time been brought under the notice of the public. Mr. Duncan Campbell Dallas, amongst others, patented the following process, known as the *Dallastype*:—

The design is photographed or drawn upon a glass plate in a medium that intercepts the actinic rays. Over the design a solution of bichromatised gelatine is poured, and when the coating thus formed is sufficiently dry, the uncoated side is exposed to the light. The parts not acted upon by light are then softened and caused to swell by treatment with cold water; this is poured off and the design is repeatedly washed with warm water till the design is free from the gelatinous mixture and allowed to dry. A mould is then taken of the surface by electrotyping, by casting, or by pressure.

Further information relative to processes of this character must be sought in the numerous Specifications of Patents which exist. The process of Photozincography will be found under its special heading. See PHOTOZINCOGRAPHY.

PHOTOGRAPHY. (From φῶς, *phōs*, *phōtos*, light; γραφή, *graphé*, a writing or a description.) The art of producing pictures by the agency of sunshine, acting upon chemically-prepared papers.

There are certain chemical compounds, and especially some of the salts of silver, which are rapidly decomposed by the influence of the sunshine, and, though more slowly, by ordinary daylight, or even by powerful artificial light. As the extent to which the decomposition is carried on, depends upon the intensity of radiation proceeding from the object, or passing through it, accordingly as we are employing the reflected or the transmitted rays, it will be obvious that we shall obtain very delicate gradations of darkening, and thus the photograph will represent in a very refined manner all those details which are rendered visible to the eye by light and shadow.

There are two methods by which photographs can be taken: the first and simplest is by *super-position*, but this is applicable only to the copying of engravings or of such botanical specimens as can be spread out upon paper, and objects which are entirely or in part transparent. The other method is by throwing upon the prepared paper the image obtained by the use of a lens fitted into a dark box—the *camera obscura.*

To carry out either of these methods certain sensitive surfaces must be produced; these therefore claim our first attention:—The artist requires—

1. Nitrate of silver. 2. Ammonia nitrate of silver. 3. Chloride of silver. 4. Iodide of silver. 5. Bromide of silver. These five chemical compounds may be regarded as the agents most essential in the preparation of photographic surfaces.

1. NITRATE OF SILVER. The crystallised salt should, if possible, always be procured. The fused nitrate, which is sold in cylindrical sticks, is liable to contamination. A preparation is sometimes sold for nitrate of silver, at from 6*d.* to 9*d.* the ounce less than the ordinary price, which may induce the unwary to purchase it. This reduction of price is effected by fusing with the salt of silver a proportion of some cupreous salt, generally the nitrate, or nitrate of potash. This fraud is readily detected by observing if the salt becomes moist on exposure to the air,—a very small admixture of copper rendering the nitrate of silver deliquescent. The evils to the photographer are, want of sensibility upon exposure, and the perishability (even in the dark) of the finished drawing.

The most simple kind of photographic paper is that washed with the nitrate of silver only; and for many purposes it answers well, particularly for copying lace or feathers; and it has this advantage that it is perfectly fixed by well soaking in *pure* warm water.

The best proportions in which this salt can be used are 60 grains of it dissolved in a fluid ounce of water. Care must be taken to apply it equally, with a quick but steady motion, over every part of the paper.

By dissolving the nitrate of silver in common rectified spirits of wine instead of water, we produce a tolerably sensitive nitrated paper, which darkens to a very beautiful chocolate-brown.

2. AMMONIA NITRATE of SILVER. Liquid ammonia is to be dropped carefully into nitrate of silver; a dark oxide of silver is thrown down; if the ammonia-liquor is added in excess, this precipitate is redissolved, and we obtain a perfectly colourless solution. Paper washed with this solution is more sensitive than that prepared with the ordinary nitrate.

3. CHLORIDE OF SILVER. This salt is obtained most readily by pouring a solution of common salt, *chloride of sodium*, into a solution of nitrate of silver. It then falls as a pure white precipitate, which changes colour in diffused daylight.

Chloridated papers are formed by producing a chloride of silver on their surface, by washing the paper with the solution of chloride of sodium, or any other chloride, and when the paper is dry, with the solution of nitrate of silver.

The most sensitive paper.—Chloride of sodium, 30 grains to 1 ounce of water; nitrate of silver, 120 grains to 1 ounce of distilled water.

The paper is first soaked in the saline solution, and after being carefully wiped with linen, or pressed between folds of blotting-paper and dried, it is to be washed twice with the solution of silver, drying it by a warm fire between each washing. This paper is very liable to become brown in the dark. Although images may be obtained in the camera obscura on this paper by about half an hour's exposure, they are never very distinct, and may be regarded as rather curious than useful.

Less sensitive paper for copies of engravings or botanical specimens.—Chloride of sodium, 25 grains to 1 ounce of water; nitrate of silver, 99 grains to 1 ounce of distilled water.

Common sensitive paper for copying lace-work, feathers, &c.—Chloride of sodium, 20 grains to 1 ounce of water; nitrate of silver, 60 grains to 1 ounce of distilled water. This paper keeps tolerably well, and, if carefully prepared, may always be depended upon for darkening equally.

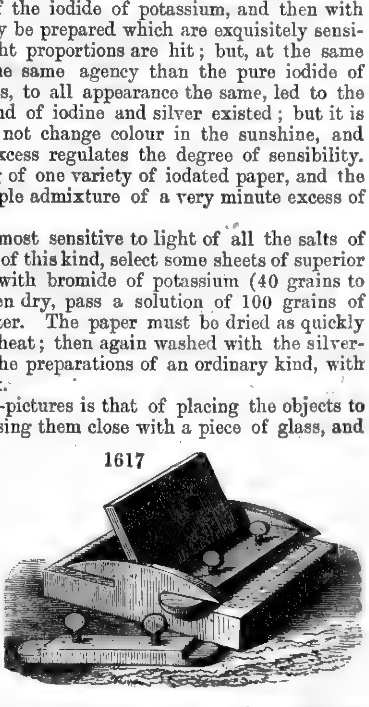
4. IODIDE OF SILVER. This salt was employed very early by Talbot, Herschel, and others, and it enters as the principal agent into Mr. Talbot's calotype-paper (see CALOTYPE). Paper is washed with a solution of the iodide of potassium, and then with nitrate of silver. By this means papers may be prepared which are exquisitely sensitive to luminous influence, provided the right proportions are hit; but, at the same time, nothing can be more insensible to the same agency than the pure iodide of silver. A singular difference in precipitates, to all appearance the same, led to the belief that more than one definite compound of iodine and silver existed; but it is now proved that pure iodide of silver will not change colour in the sunshine, and that the quantity of nitrate of silver in excess regulates the degree of sensibility. Experiment has proved that the blackening of one variety of iodated paper, and the preservation of another, depends on the simple admixture of a very minute excess of the nitrate of silver.

5. BROMIDE OF SILVER. Bromide is the most sensitive to light of all the salts of silver. To prepare a highly sensitive paper of this kind, select some sheets of superior glazed post, and wash it on one side only with bromide of potassium (40 grains to 1 ounce of distilled water) over which, when dry, pass a solution of 100 grains of nitrate of silver in the same quantity of water. The paper must be dried as quickly as possible without exposing it to too much heat; then again washed with the silver-solution, and dried in the dark. Such are the preparations of an ordinary kind, with which the photographer will proceed to work.

The most simple method of obtaining sun-pictures is that of placing the objects to be copied on a piece of prepared paper, pressing them close with a piece of glass, and exposing the arrangement to sunshine: all the parts exposed darken, while those covered are protected from change, the resulting picture being *white* upon a *dark ground*.

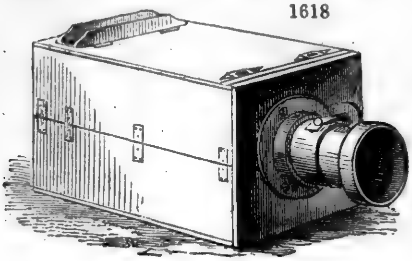
For the multiplication of photographic drawings, it is necessary to be provided with a frame and glass, called a *copying frame*. The glass must be of such thickness as to resist considerable pressure, and it should be selected as colourless as possible, great care being taken to avoid such as have a tint of yellow or red, these colours preventing the permeation of the most efficient rays. *Fig.* 1617 represents the frame, showing the back, with its adjustments for securing the close contact of the paper with every part of the object to be copied.

1617

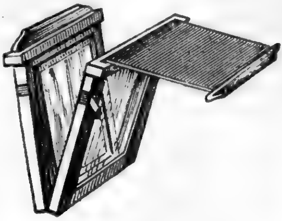


Having placed the frame face downwards, carefully lay out on the glass the object to be copied, on which place the photographic paper very smoothly. Having covered this with the cushion, which may be either of flannel or velvet, fix the back, and adjust it by the bar, until every part of the object and paper are in the closest possible contact; then turn up the frame and expose to sunshine.

1618



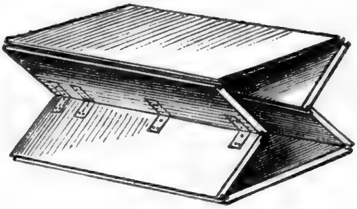
1619



It should be here stated, once for all, that such pictures, howsoever obtained, are called *negative photographs*;—and those which have their lights and shadows correct as in nature—dark upon a light ground—are *positive photographs.* The mode of effecting the production of a *positive* is, having, by fixing, given permanence to the negative picture, it is placed, face down, on another piece of sensitive paper, when all the parts which are white on the first, admitting light freely, cause a dark impression to be made on the second, and the resulting image is correct in its lights and shadows, and also as it regards right and left.

For obtaining pictures of external nature, the Camera Obscura of Baptista Porta is employed.

1620



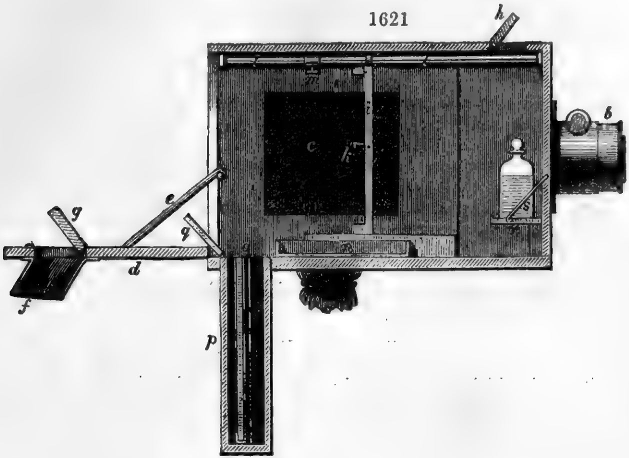
The figures (*figs.* 1618, 1619, 1620) represent a perfect arrangement, and, at the same time, one which is not essentially expensive. Its conveniences are those of folding (*fig.* 1620), and thus packing into a very small compass, for the convenience of travellers.

Fig. 1618 exhibits the instrument complete. *Fig.* 1619 shows the screen in which the sensitive paper is placed, the shutter being up and the frame open that its construction may be seen.

Camera obscuras of a more elaborate character are constructed, and many of exceeding ingenuity, which give every facility for carrying on the manipulations out of doors.

Fig. 1621 is a section of a very useful instrument, and *fig.* 1622 its external form. With a view to its portability it is constructed so as to serve as a packing-case for all the apparatus required. *a* is a sliding door, which supports the lens. *b*, *c*, *c* are side-openings fitted with cloth-sleeves to admit the operator's arms. *d* is a hinged door at the back of the camera, which can be supported like a table by the hook *e*. *f* is the opening for looking into the camera during an operation. This opening is closed when necessary by the door *g*, which can be opened by the hand passed into the camera through the sleeves *c*. The yellow-glass window which admits light into the camera during an operation is under the door, *h*. *i* is the sliding frame for holding the focussing glass, or the frame with the prepared glass, either of which is fastened to the sliding frame by the check, *k*. The frame slides along the rod, *l l*, and can be fitted to the proper focus by means of the step *m*. *n* is the gutta-percha washing-tray. *o* is an opening in the bottom of the instrument near the door, to admit the well, *p*, and which is closed when the well is removed by the door. The well is divided into two cells, one of which contains the focussing glass, and the other the glass trough, each in a frame adapted to the sliding frame, *i*. On each side of the sliding door that supports the lens, *a*, there is within the camera a small hinged-table, *r*, supported by a bracket, *s*.

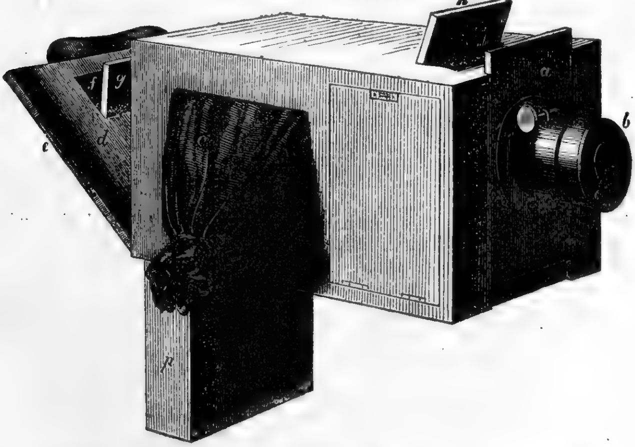
1621



These two tables serve to support the bottles that contain the solutions necessary to be applied to the glass plate after its exposure to the lens.

For supporting any of these camera obscuras, tripod stands are employed; these are now made in an exceedingly convenient form, being light, at the same time that

1622



they are sufficiently firm to secure the instrument from any motion during the operation of taking a picture.

The true photographic artist, however, will not be content with a camera obscura of this or any other kind. He will provide himself with a tent, in which he may be able to prepare his plates, and subsequently to develop and to fix his pictures. Many kinds of tent have been brought forward; but we have not seen any one which unites perfectly all that can be desired, within a limited space, and which possesses the great recommendation of lightness.

Smartt's photographic tent, however, appears to meet nearly all the conditions required. In this tent an endeavour has been made to obviate many of the inconveniences complained of, especially as to working space, firmness, simplicity, and portability. It is rectangular in form, is 6 feet high in the clear, and 3 feet square, affording table space equal to 36 inches by 18 inches, and ample room for the operator to manipulate with perfect ease and convenience. The table is made to fold up when not in use; and in place of the ordinary dish for developing, a very efficient and portable tray is provided, made of india-rubber cloth, having its two sides fixed and rigid, and its two ends moveable; it thus folds up into a space but little larger than one of its sides. The working space of the table is economised thus:—a portion of it is occupied in the way just described: the silver-bath is suspended from the *front* of the table, and rests upon a portion of the framework of the tent. This arrangement leaves ample space on the table for manipulating the largest-sized plates. The collodion pourer, the plate-developing holder, the developing cups, and the water-bottle, have all special points in construction. The entire weight of the tent is 20 lbs., and it is easily erected or taken down by one person. Many improvements have been introduced in this tent, which now render it nearly perfect.

The processes of most importance may be divided as follow:—

1. The *Copying* process, already described.
2. The *Daguerreotype*. See DAGUERREOTYPE.
3. The *Calotype*. See CALOTYPE.
4. The *Collodion* process, which must now be described

THE COLLODION PROCESS.

The difficulty with which we are met in any attempt to describe this photographic process is, that it is almost hopeless to find two photographers who adopt precisely the same order of manipulation; and books almost without number have been published, each one recommending some special system.

By general consent the discovery of the collodion process, as now employed, is given to the late Mr. Scott Archer. It will, therefore, be considered quite sufficient to give the details of his process, which has really been but little improved on since its first introduction.

To prepare the collodion. Thirty grains of gun-cotton should be taken and placed in 18 fluid ounces of rectified sulphuric ether, and then 2 ounces of alcohol should be added, making thus 1 imperial pint of the solution. The cotton, if properly made, will dissolve entirely; but any small fibre which may be floating about should be allowed to deposit, and the clear solution poured off.

To iodise the collodion. Prepare a saturated solution of iodide of potassium in alcohol—say 1 ounce, and add to it as much iodide of silver, recently precipitated and well washed, as it will take up: this solution is to be added to the collodion, the quantity depending on the proportion of alcohol which has been used in the preparation of the collodion.

Coating the plate. A plate of perfectly smooth glass, free from air-bubble or striæ, should be cleaned very perfectly with a few drops of ammonia on cotton, and then wiped with a very clean cotton cloth.

The plate must be held by the left hand perfectly horizontal, and then with the right a sufficient quantity of iodised collodion should be poured into the centre, so as to diffuse itself equally over the surface. This should be done coolly and steadily, allowing it to flow to each corner in succession, taking care that the edges are well covered; then gently tilt the plate, that the superfluous fluid may return to the bottle from the opposite corner to that by which the plate is held. At this moment the plate should be brought into a vertical position, when the diagonal lines caused by the fluid running to the corner will fall one into the other, and give a clear flat surface. To do this neatly and effectually some little practice is necessary, as in most things; but the operator should by no means hurry the operation, but do it systematically, at the same time not being longer over it than is actually necessary, for collodion being an ethereal compound evaporates rapidly. Many operators waste their collodion by imagining it is necessary to perform this operation in great haste; but such is not the case, for an even coating can seldom be obtained if the fluid is poured on and off again too rapidly; it is better to do it steadily, and submit to a small loss from evaporation. If the collodion becomes too thick, thin it with the addition of a little fresh and good ether.

Exciting the plate. Previous to the last operation, it is necessary to have the bath ready, which is made as follows:—

Nitrate of silver	30 grains.
Distilled water	1 ounce.

Dissolve and filter.

The quantity of this fluid *necessary* to be made must depend upon the *form of trough to be used*, whether horizontal or vertical, and also upon the size of the plate. With the vertical trough a glass dipper is provided, upon which the plate rests, preventing the necessity of any handle or the fingers going into the liquid. If however, the glass used is a little larger than required, this is not necessary. Having then obtained one or other of these two, and filtered the liquid previously, the plate, free from any particle of dust, &c., is to be *immersed steadily and without hesitation*; for if a pause should be made in any part, a line is sure to be formed, which will print in a subsequent part of the process.

The plate being immersed in the solution must be kept there a sufficient time for the liquid to act freely upon the surface, particularly if a negative picture is to be obtained. *As a general rule, it will take about two minutes, but this will vary with the temperature of the air at the time of operating, and the condition of the collodion.* In cold weather, or indeed anything below 50° Fahr. the bath should be placed in a warm situation, or a proper decomposition is not obtained under a very long time. Above 60° the plate will be certain to have obtained its maximum of sensibility by two minutes' immersion, but below this temperature it is better to *give a little extra time.*

To facilitate the action, let the temperature be what it may, the plate must be lifted out of the liquid two or three times, which also assists in getting rid of the ether from the surface, for unless this is thoroughly done a uniform coating cannot be obtained; *but on no account should it be removed until the plate has been immersed about half a minute*, as marks are apt to be produced if removed sooner.

The plate is now ready to receive its impression in the camera obscura. This having been done, the picture is to be developed.

The development of the image. To effect this the plate must be taken again into the dark room, and with care removed from the slide to the levelling stand.

It will be well to caution the operator respecting the removal of the plate. Glass, as before observed, is a bad conductor of heat; therefore, if in taking it out we allow it to rest on the fingers at any one spot too long, that portion will be warmed through to the face, and as this is not done until the developing solution is ready to go over, the action will be more energetic at those parts than at others, and consequently destroy the evenness of the picture. We should, therefore, handle the plate with care, as if it already possessed too much heat to be comfortable to the fingers, and that we must therefore get it on the stand as soon as possible.

Having then got it there, we must next cover the face with the developing solution. This should be made as follows :—

Pyrogallic acid	5 grains.
Glacial acetic acid	40 minims.
Distilled water	10 ounces.

Dissolve and filter.

Mr. Delamotte employs

Pyrogallic acid	9 grains.
Glacial acetic acid	2 drachms.
Distilled water	3 ounces.

Now, in developing a plate, the quantity of liquid taken must be in proportion to its size. A plate measuring 5 inches by 4 will require half an ounce; less may be used, but it is at the risk of stains; therefore we would recommend that half an ounce of the above be measured out, into *a perfectly clean measure*, and to this from 8 to 12 drops of a 50-grain solution of nitrate of silver be added.

Pour this quickly over the surface, taking care not to hold the measure too high, and not to pour all on one spot, but having taken the measure properly in the fingers, begin at one end, and carry the hand forward; immediately blow upon the face of the plate, which has the effect not only of diffusing it over the surface, but causes the solution to combine more equally with the damp surface of the plate; it also has the effect of keeping any deposit that may form in motion, which if allowed to settle, causes the picture to come out mottled. A piece of white paper may now be held under the plate, to observe the development of the picture: if the light of the room is adapted for viewing it in this manner, well; if not, a light must be held below, but in either case arrangements should be made to view the plate easily whilst under the operation: a successful result depending so much upon obtaining sufficient development without carrying it too far.

As soon as the necessary development has been obtained, the liquid must be poured off, and the surface washed with a little water, which is easily done by holding the plate over a dish, and pouring water on it; taking care, both in this and a subsequent part of the process, to hold the plate horizontally, and not vertically, so as to prevent the coating being torn by the force and weight of water.

Protosulphate of iron, which was first introduced as a photographic agent in 1840 by Mr. Robert Hunt, may be employed, instead of the pyrogallic acid, with much advantage. Generally the collodion portraits are now developed by the iron salt. The following are the best proportions:—

Protosulphate of iron	1 ounce.
Acetic acid	12 minims.
Distilled water	1 pint.

This is used in the same manner as the former solutions.

Fixing of image. This is simply the removal of iodide of silver from the surface of the plate, and is effected by pouring over it, after it has been dipped into water, a solution of hyposulphite of soda, made of the strength of 4 ounces to 1 pint of water. At this point daylight may be admitted into the room, and indeed we cannot judge well of its removal without it. We then see by tilting the plate to and fro the iodide gradually dissolve away, and the different parts left more or less transparent, according to the action of light upon them.

It then only remains to thoroughly wash away every trace of the hyposulphite of soda, for should any salt be left, it gradually destroys the picture. The plate should therefore either be immersed with great care in a vessel of clean water, or what is better, water poured gently and carefully over the surface. After this it must be placed upright to dry or be held before a fire.

The fixing processes. The most important part of Photography, and one to which the least attention has been paid, is the process of rendering permanent the beautiful images which have been obtained. Nearly all the fine photographs with which we are now familiar are not permanent. This is deeply to be regretted, especially as there appears to be no necessity for their fading away. In nearly all cases the fading of a photograph may be referred to carelessness; and it is not a little startling, and certainly very annoying, to hear a very large dealer in photographic pictures declare that the finest pictures by the best photographers are the first to fade. This is, no doubt, to be accounted for by the demand which there is for their pictures, leading to a fatal rapidity in the necessary manipulatory details.

There is no necessity for a photograph to fade if kept with ordinary care. It should be at all events as permanent as a sepia drawing. Hyposulphite of soda is the true fixing agent for any of the photographic processes, be they Daguerreotype, calotype, collodion, or the ordinary process for producing positive prints. It should be understood, whichever of the salts of silver are employed, that by the action of the solar rays either oxide of silver or metallic silver is produced, and the unchanged chloride, iodide, or bromide can be dissolved out by the use of the *hyposulphite of soda*.

The photographic picture on paper, on metal, or on glass, is washed with a strong solution of the hyposulphite of soda, and the silver salt employed combines with it, forming a peculiarly sweet compound, the hyposulphite of silver; this is soluble in water, and hence we have only to remove it by copious ablutions. The usual practice is to place the pictures in trays of water and to change the fluid frequently. In this is the danger, and to it may be traced the fading of nine-tenths of the pictures prepared on paper.

Paper is a mass of linen or cotton fibre; howsoever fine the pulp may be prepared, it is still full of capillary pores, which, by virtue of the force called capillarity, holds with enormous tenacity a large portion of the solid contents of the water. If we make a solution of a known strength of the hyposulphite of soda, and dip a piece of paper into it, it will be found to have lost more of the salt than belongs to the small quantity of water abstracted by the paper. Solid matter in excess has been withdrawn from the solution. So a photographic picture on paper holds with great tenacity one or other of the hyposulphites. By soaking there is of course a certain portion removed, but it is not possible by any system of soaking to remove it all.

The picture is, however, prepared in this manner, and slowly, but surely, under the combined influences of the solar rays and atmospheric moisture, the metallic silver loses colour, *i. e.* the photograph fades.

The only process to be relied on demands that every picture should be treated separately. First, any number may be soaked in water, and the water changed; by this means the excess of the hyposulphite of silver is removed. Then each picture must be taken out and placed upon a slab of porcelain or glass, and being fixed at a small angle, water should be allowed to flow freely over and off it. Beyond this, the operator should be furnished with a piece of soft sponge, and he should maintain for a long time a dabbing motion. By this mechanical means he disturbs the solid matter held in the capillary tubes, and eventually removes it. The labour thus bestowed is rewarded by the production of a permanent picture, not to be secured by any other means.

A process has recently been introduced (1874) which is highly spoken of. It consists essentially in mixing recently-precipitated bromide of silver with very pure gelatine. This creamy, semi-opaque mixture is poured on glass-plates, and these are dried with application of moderate heat in perfect darkness. The plates are rendered highly sensitive in the usual manner. It is said that in good light a portrait can be taken in five seconds.

PHOTOMETRY. The measurement of light, or of illuminating power. See ILLUMINATION.

PHOTO-SCULPTURE. The following description of this art is written by the late M. A. Claudet, F. R. S., who most successfully practised it:—'This beautiful application of photography is called Photo-sculpture, and is the invention of M. Willème, an eminent French sculptor. Before explaining how M. Willème was led to this discovery, let me remind you that photography itself was invented by painters of talent—by artists who, while using the camera obscura for studying the subject of their intended pictures, were struck with the beauty of those natural representations. In contemplating them they naturally desired that the pictures could be permanently fixed. Considering that these pictures were formed by the light reflected from the objects, they essayed to fix them by availing themselves of the known scientific fact that light had the property of blackening certain chemical compounds. The flash of that idea was enough; their genius and perseverance solved the problem, and they created that art which they desired so much—photography. A similar and no less instructive story may be told of photo-sculpture. M. Willème was in the habit, whenever he could procure photographs of his sitters, of endeavouring to communicate to the model the correctness of those unerring types. But how should he raise the outlines of flat pictures into solid form? Yet these single photographs, such as they were, could serve him to measure exactly profile outlines. He could indeed, by means of one of the points of a pantograph, follow the outline of a photograph, while with the other point directed on the model, he ascertained and corrected any error which had been communicated to his work during the modelling. What he could do with one view or one single photograph of the sitter, he might do also with several other views if he had them. This was sufficient to open the inquiry of an ingenious mind. He saw at once that if he had photographs of many other profiles of the sitter, taken at the same moment, by a number of camera obscuras placed round, he might alternately and consecutively correct his model by comparing the profile outline of each photograph with the corresponding outline of the model. Such was the origin of a marvellous and splendid discovery. But it soon naturally occurred to him, that instead of correcting his model when nearly completed, he had better work with the pantograph upon the rough block of clay, and cut it out gradually all round in following one after the other the outline of the photographs. Now supposing that he had twenty-four photographs, representing the sitter in as many points of view (all taken at once), he had but to turn the block of clay after every operation $\frac{1}{24}$th of the base upon which it is fixed, and to cut out the next profile, until the block had completed its entire revolution, and then the clay was transformed into a perfect solid figure of the twenty-four photographs; the statue of the bust was made. When this is once explained, everyone must be struck with admiration at the excellence of the process. It is so sure, and so simple, that we are surprised it has not been thought of before.'

PHOTOZINCOGRAPHY. This is the name given by Major-General Sir Henry James, R.E., Director of the Ordnance Survey, who has thus described the process:—

'For the purpose of producing rapidly and in large numbers, fac-similes of plans, drawings, written and printed documents, &c., of the same size as the originals, or to any required lesser scale, the present Director of the Ordnance Survey successfully introduced in 1859, a method combining the accuracy of photography with the facility of printing from zinc-plates, and named the process Photozincography. It is now extensively used at Southampton for supplying the public, at a low cost, with fac-similes of some of the most interesting and valuable State papers that are preserved among the national manuscripts of the United Kingdom.

'The fac-similes being in ink of which carbon is the basis, are not liable to fade, like photographic prints in silver; for although the silver is coated with a film of gold in the toning bath, it slowly yields to atmospheric influences, and to the long-continued action of small traces (almost impossible to eradicate) of substances employed in the manipulation.

'In the process of zincography a tracing of the document is made in a greasy ink, and applied to a zinc-plate, from which any desired number of impressions may be printed; but in photozincography a photograph is prepared in such a manner that it may be transferred to a zinc-plate, the prints from which are free therefore from any error of the draughtsman's hand.

'In copying maps, engravings, manuscripts, &c., a negative of the object is taken on a glass-plate, and the silver deposit blackened with corrosive sublimate and ammonium hydrosulphate; a sun-print is taken from the negative on paper, coated with gelatine and bichromate of potass, which surface when exposed to the influence of light, is insoluble in water at a moderately high temperature.

'The print is uniformly covered all over with greasy transfer ink, and afterwards washed with warm water to dissolve the gelatine unacted upon by light, and so carry away the ink upon it, which now remains only on the insoluble portions. In this way a print in a greasy carbon ink is prepared, which has both the appearance and the properties of an ordinary tracing in lithographic ink, and can be transferred to zinc or stone in the usual manner.

'The paper used for the carbon print should be tough, free from loose fibres, and have a surface that will remain almost undisturbed when saturated with water, and subjected to gentle friction. The double-elephant bank-post manufactured by Cowan and Sons, Cannon Street, London, answers these requirements, and has been found more suitable than any other paper that has been tried at Southampton.

'The sensitizing solution is made by dissolving gelatine in hot water, and adding potassium bichromate in solution in the following proportions:—

Nelson's best patent fine gelatine	3 ozs.
Potassium bichromate	2 „
Hot water	50 „

The mixture must be made and preserved in the dark.

'When used for coating the paper, it is put into a flat dish and kept at a temperature of about 100° Fahr., by means of a water-bath; the paper is floated on its surface for two or three minutes, then hung up to dry by two corners, floated again for a shorter period, but at a lower temperature, so as not to remove the first coating, and dried in a reversed position; by this double application, with the aid of a high temperature maintained during the act of drying, a uniform surface is obtained.

'The coated paper, which is very sensitive to light, is then smoothed by being passed through a lithographic press, and may be used any time within a week of its preparation, but the best results in making copies of maps, engravings, manuscripts, &c., are obtained when the sensitized paper has not been kept longer than two or three days; after a week the paper becomes useless, it being almost impossible to clear the ink from the ground of the print on account of the uniform reduction of a portion of the potassium bichromate. The sensitizing mixture may be preserved for further use for a considerable length of time, if kept in an opaque vessel, free from organic matter, and in a dark room; an earthenware jar is a convenient receptacle, as the mixture when cold becomes a jelly, and the jar can be put in hot water without injury, so as to melt its contents when required for preparing more paper.

'The time required to obtain a suitable sun-print on the prepared paper varies perhaps from one to twenty minutes, with the amount of light, the age of the paper, and the condition of the negative; it may generally be known by the exposed portions of the yellow bichromate surface becoming a dark olive colour; the printing should then be stopped, and the paper coated with transfer ink. Paper recently prepared requires rather longer exposure than that two or three days old, as, if the latter be darkly printed, it is almost impossible to wash off the superfluous ink.

'To make the transfer ink, 3 ounces of Burgundy pitch are melted in an iron saucepan, ½ an ounce of white wax, and ½ an ounce of palm-oil are added, and then by degrees 1 ounce of finely-powdered bitumen of Judæa; the mixture is stirred and heated over a fire until it commences to burn; after the flame is extinguished by the lid of the saucepan, 8 ounces of best lithographic printing ink, rubbed up with 4 ounces of middle lithographic varnish are gradually added, and when uniformly mixed, the composition is ground in small portions on a hot slab with a stone muller.

'When this ink is required for use, a little of it is spread upon a stone and thinned with turpentine, according to the consistency required for the nature of the work about to be transferred. To coat the paper, a lithographic stone is uniformly inked with a printing roller charged with the composition, the sun-print is laid face downwards on the stone, and passed through a lithographic press in a dark room; it is detached from the stone, reversed in position, and passed through the press a second time to ensure a sufficient and uniform coating of ink. After the print has been inked, it is floated face upwards on water at about 90° Fahr., for a few minutes, when by an unequal swelling of the gelatine the detail of the image can be distinguished. To prevent stains, that would inevitably spoil fine work, it is necessary that no water be allowed to fall upon the face of the print while it is floating. After a few minutes, the paper is raised from the surface of the water, and laid evenly, with the inked face uppermost, on a slightly-inclined surface of glass or earthenware, and a fine soft sponge dipped in tepid water is repeatedly passed over it with a light hand, plenty of water being used; this removes the gelatine and bichromate that have not been affected by light, and they carry off with them the ink that was on their surface, leaving it only on the parts of the print that have been rendered insoluble. Very gentle friction should be used, and during the process of sponging, the print should be soaked face downwards in warm water for a few minutes, to assist in loosening the ink and removing the gelatine. Soaking in this manner, for some little time, has a great effect in preventing blemishes, in lessening the amount of friction which is sometimes liable to break up the finer parts of the print, and in the case of sensitive paper, over-exposed to light, of improving the resulting transfer. When the chromo-carbon print is sharp and clear, it should be well washed with tepid water so as to remove every trace of soluble gelatine, as if any intervened between the inky surface and the zinc plate (or lithographic stone) with which it is to be pressed in contact, there would be a flaw in the transfer. After this washing, the print is dried and transferred to zinc or stone, in the same way as an ordinary tracing in lithographic ink, only from the ink not having been long exposed to the atmosphere, it is seldom necessary to pass it more than once through the press.

'The same number of impressions can be obtained as if the transfer had been effected by means of a tracing in greasy ink.

'In reproducing a large-sized map by photozincography, a series of rectangles are drawn on it suitable to the size of the camera, and negatives are taken which shall overlap each portion, the chromo-carbon prints from these being joined together before they are transferred to the zinc-plate. To ensure a good result, the negatives should be as nearly as possible of uniform density, the prints finished with a corresponding thickness of ink on their surfaces, and the joining effected by cutting away the overlapping portions in such a manner as not to interfere with the names or prominent objects on the map. In this way photozincographs exceeding 3 feet in length by 2 feet in breadth have been successfully prepared.

'Photozincography has also been applied to the representation of buildings, natural objects, scenery, &c., with more or less success, according to the strength of the contrasts of light and shade presented by the object; the difficulty being to obtain fine gradations of shade or half-tone. In this application of the art, the glass negatives taken are left in the same condition as they would be used for making ordinary silver prints of views and scenery, for if they were intensified with corrosive sublimate and ammonium hydro-sulphate, as described in copying maps and engravings (where sharp lines are required), all gradations of shade would be destroyed.

'Chromo-carbon prints are made from these negatives in the manner before described, and transferred to zinc, the only difference in their preparation being that the paper coated with bichromate and gelatine is kept from four to five days after preparation before being printed upon, and the transfer-ink is a little more burnt, when being prepared, than the ink that is used for prints without gradations of shade; considerable experience is necessary in washing the prints so as to bring out the full effect of the shadows, and much of the success of the process also depends on the skill and care of the zinc-printer. An application of glycerine to the zinc-plate is found to assist materially in keeping the transfer clean, and preventing the fine portions from being clogged with ink; 1 ounce of glycerine is added to 1 pint of freshly-dissolved gum Arabic of the usual consistency, made neutral to test-paper by the addition of lime-water, and 2 ounces of this mixture added to 12 ounces of water are used for wiping over the surface of the plate; the addition of the glycerine seems to keep the surface moist for a longer time than the simple application of water, and renders the roller less liable to 'catch.' Glycerine is also used in this manner in ordinary zincographic printing, when a very large number of impressions are required from a plate.

'Photozincographic views of natural objects generally have a better effect when printed on tinted and enamelled paper than on an ordinary white ground, and paper so coated adds materially, by lifting the ink better than a plain surface, in keeping the transfer in good condition on the zinc. A paper of an agreeable tint may be prepared with the following composition:—

Size melted in 10 pints of water	20 oz.
Zinc white, ground in water and weighed wet	14 lbs.
Oxide of iron	3 oz.
Chrome yellow	200 grains.
Vermilion	30 „

'The mixture is brushed while warm over the paper, any streaks being obliterated with a flat camel's-hair brush; and when the coating is dry, a second layer is applied in a similar manner.'

PHTHALIC ACID. A crystallised substance produced by the action of nitric acid on rubian. See Madder.

PHYTOGRAPHY. See Nature-Printing.

PIASSABA FIBRE, obtained from the *Attalea funifera,* and used in Brazil for rope-making. It is this palm which also yields Coquilla nuts.

PICAMARE. A colourless oil in wood-tar, discovered by Reichenbach. See Distillation, Destructive; Naphtha; Pyroxilic Spirit.

PICKLES are various kinds of vegetables and fruits preserved in vinegar. The preparation of pickles belongs rather to a book on cookery. The peculiar and beautiful green colour which has been frequently imparted to pickles is due in nearly all cases to the use of a salt of copper. This is in the highest degree injurious, and cannot be too strongly deprecated. The presence of copper may be detected by putting the blade of a perfectly clean knife, or still better, a polished piece of soft iron, into the suspected pickle; it will, if copper be present, become coated in a short time with a cupreous film. It is satisfactory to find that most of our large pickle-manufacturers are content to sacrifice the colour, at one time so much looked to; and they now furnish the public with pickles which are free from any metallic contamination.

PICOLINE, $C^{12}H^7N$ (**C^6H^7N**). A nitryle base, isomeric with aniline, discovered by Anderson in coal-naphtha and bone-oil. It is also contained in the shale-naphtha and crude chinoline.

PICRIC ACID. One of the products of the action of nitric acid upon phenol: it may also be obtained from a considerable number of other organic compounds, amongst which may be mentioned an Australian resin, from *Xanthorrhœa hastilis* (Stenhouse), salicin, indigo, &c; but the best source is undoubtedly impure phenol, or even the coal-tar oils that distil at 180° and 200° Cent. (Laurent). See Carbolic Acid.

The reaction between nitric acid and phenol is very violent. It is therefore necessary to observe many precautions when operating upon considerable quantities of material. When the first violent action has ceased, fresh quantities of nitric acid are added, and the mixture is heated in order to facilitate the reaction. On allowing the mixture to cool, after having added water, a yellowish, very bitter mass is obtained, which is washed with water in order to remove the excess of nitric acid. This mass consists of impure picric acid, and treated with cold or hot water, it furnishes solutions which, when filtered, may be employed for the ordinary processes of dyeing.

It is, however, preferable to purify the acid and to prepare it in the crystallised condition.

For this purpose two processes may be employed. The yellow mass may be extracted by boiling water sufficiently acidulated with sulphuric acid to render comparatively insoluble the yellow resinous matters. (These yellow matters are produced by an incomplete transformation, partly of the phenol, but principally of the neutral oils, and other foreign matters accompanying it, and which have also been attacked by the nitric acid.) The picric acid crystallises from the solution (the more easily for being acidulated with sulphuric acid), and is deposited in the form of crystalline plates of a light yellow colour. But these crystallisations cause the loss of a considerable quantity of substance, and by no means eliminate completely the yellow tarry matter. It is therefore better to convert the impure acid into a salt which may be easily purified, and afterwards to precipitate the acid from it. The picrate of potassium is very applicable for this purification, as it is only slightly soluble in cold water, whilst it is readily soluble in boiling.

But in operating upon a large scale, the filtration of large quantities of the salt becomes extremely difficult, as the liquids, even when boiling and contained in heated funnels, have a great tendency to crystallise on the filters, which then become choked.

Several manufacturers therefore adopt another process, which consists in saturating a boiling solution of picric acid with carbonate of soda, excess being avoided, for fear of dissolving the yellow resinous matter. The boiling matters are filtered to separate this resin, and to the filtrate a further quantity of carbonate of soda is added. This causes the bulk of the picrate of soda to crystallise out, as this salt is nearly insoluble in solutions containing an excess of alkaline carbonate. The small quantity of picrate still remaining in the mother-liquors may be precipitated by the addition of a salt of potassium.

The crystallised picrate of soda thus obtained is then dissolved, and its boiling solution is decomposed by an excess of sulphuric acid. The picric acid thus separated being very insoluble in the mother-liquors containing the acid sulphate of soda, crystallises almost entirely on cooling; when drained, washed with a little cold water, and pressed, it is almost chemically pure.

Picric acid is used for dyeing silk and wool of a yellow colour. Its colouring power is very considerable, and it exhibits a great affinity for nitrogenised substances. The colour resists the action of light very well, but it is somewhat affected by washing, particularly with soap. It is rendered more stable by mordanting the material with alum.

Cotton, hemp, and flax, do not show any affinity for picric acid. The acid may therefore be employed to distinguish silk and wool from cotton and flax. For this purpose it is only necessary to plunge the tissue in a boiling solution of picric acid, and then wash in water. The silk and wool will assume an intense yellow colour, whilst the cotton and flax remain perfectly colourless.

The use of picric acid for dyeing purposes was first suggested by M. Guinon of Lyons, in 1845.

Picric acid, under the influence of reducing agents, produces other colouring-matters; treated with ferrous salt and an alkali, for example, it produces a red acid (Wöhler's nitro-hæmatic acid). Under the influence of cyanide of potassium, again, it gives rise to a purple potassium salt (Mr. Hlasiwetz's isopurpurate of potassium). This purpurate, treated with an ammoniacal salt, produces an ammonaical compound, which, when applied to dyeing, acts like the murexide of uric acid, giving, in fact, precisely the same tints. Under the influence of chloride of tin, picric acid may even produce, blue, purple, and red colouring-matters; but the nature of these substances is very little known, and not one of them has as yet (1862) received any practical application.—*Hofmann.*

Instead of free picric acid, the alkaline picrates have been used in dyeing. This practice is to be condemned since these salts are highly explosive, and are indeed used on the Continent as explosive agents. Picrate gunpowder is prepared, in which picrate of potash replaces saltpetre. Picrate of ammonia enters into the composition of many coloured fires. The isopurpurate of potash mentioned above is now used as a dye under the French name of *Grénat soluble.*

PICROMEL is the name given by M. Thénard to a black bitter principle which he supposed to be peculiar to the bile. MM. Gmelin and Tiedemann have since called its identity in question.

PICROTOXIN (*Picrotoxic acid*) is an intensely bitter poisonous vegetable principle, extracted from the seeds of the *Menispermum cocculus* (Cocculus Indicus). It crystallises in small white needles, dissolving in boiling water and in alcohol. It does not combine with acids, but forms combinations with alkalis.

PIETRA DURA. Ornamental work, executed in coloured stones, representing flowers, fruits, birds, and the like. The Florentine work and the inlaid marble work of Derbyshire are of this character.

PIG IRON. See Iron.

PIGMENTS. See Colours; Paints.

PIMENTO. (*Myrtus pimenta*, Linn.; *Eugenia pimenta*, De Candolle.) Allspice, or Jamaica pepper. This plant is cultivated in Jamaica in regular *Pimento walks.* The full sized-fruit is gathered green and sun dried, during which process it is frequently immersed. It is sent to the English market in bags of 1 cwt. each. This fruit consists, according to Bonastre's complicated analysis, of:—

	Shells or capsules	Kernels
Volatile oil	10·0	5·0
Green oil	8·4	2·5
Concrete oil	0·9	1·2
Extract containing tannin	11·4	39·8
Gummy extract	3·0	7·2
Brown matter dissolved in potash	4·0	8·0
Resinous matter	1·2	3·2
Sugar, uncrystallised	3·0	8·0
Gallic and malic acids	0·6	1·6
Vegetable fibre	50·0	16·0
Ashes charged with salts	2·8	1·9
Moisture and loss	4·1	4·8

PINANG, or Betel Nut. See Areca.

PINCHBECK. A yellow metal, composed of 3 ozs. of zinc to 1 lb. of copper. See Alloys; Brass.

PINCOFFIN, or *Alizarine commerciale.*—Under these names, some years ago, Messrs. Pincoff and Co., of Manchester, brought into the market a garancin which yields very fine violet tints without requiring clearing. The other colours obtained with it are equally satisfactory. Pincoffin is a garancin prepared, and more especially washed, with the greatest care. It is made as neutral as possible, and then exposed to a heat above 100° C., by means of high-pressure steam. Under these circumstances, a certain quantity of brown colouring-matter is destroyed or rendered inert, and the dried product immediately yields fine tints.

PINE-APPLE YARN and **CLOTH.** In Mr. Zincke's process, patented in December 1836, for preparing the filaments of this plant, the *Bromelia Ananas*, the leaves being plucked, and deprived of the prickles round their edges by a cutting instrument, are then beaten upon a wooden block with a wooden mallet, till a silky-looking mass of fibres is obtained, which are to be freed by washing from the green fecula. The fibrous part must next be laid straight, and passed between wooden rollers. The leaves should be gathered between the time of their full maturity and the ripening of the fruit. If earlier or later, the fibres will not be so flexible, and will need to be cleared by a boil in soapy water for some hours, after being laid straight under the pressure of a wooden grating, to prevent their becoming entangled. When well washed and dried, with occasional shaking out, they will now appear of a silky fineness. They may be then spun into porous rovings, in which state they are most conveniently bleached by the ordinary methods.

PINES. A numerous family of cone-bearing timber trees. The wood, which is extensively used, is imported under the names of American, Baltic, Dantzic, Memel, Norway, and Riga timber, Swiss deals, &c. The New Zealand pine, called also the Cowdie or Kaurie (the *Dammara Australis*), is not a true pine.

The Pinus sylvestris. The wild pine, or Scotch fir, yields the yellow deal.

The Abies excelsa. The Norway spruce-fir, the white deal. See Abies.

The Abies picea. The silver fir, a whitish deal, much used for flooring.

The Larix Europæa. The larch. This wood is much employed in Switzerland.

The Pinus strobus. The Weymouth pine, is much used in the Northern United States.

The Pinus Australis. The southern pine, yellow pine, or pitch pine. Of this wood nearly all the houses of the Southern United States are built. It is imported into Liverpool as the Georgia pitch pine.

There are numerous others, as the American larch, the balm-of-Gilead fir, the spruce-firs, &c., which are employed in various districts for ship and house building, but they scarcely require any special notice here.

PINEY TALLOW is a concrete fat obtained by boiling with water the fruit of the *Vateria indica*, a tree common upon the Malabar coast. It seems to be a substance intermediate between tallow and wax; partaking of the nature of stearine. It melts at 97½° F., is white or yellowish, has a spec. grav. of 0·926; is saponified by alkalis, and forms excellent candles. Dr. Benjamin Babington, to whom we are indebted for all our knowledge of piney tallow, found its ultimate constituents to be, 77 of carbon, 12·3 of hydrogen, and 10·7 of oxygen. See Oils.

PIN MANUFACTURE. (*Fabrique d'épingles*, Fr.; *Nadelfabrik*, Ger.) A pin is a small bit of wire, commonly brass, with a point at one end and a spherical head at the other. In making this little article, there are no less than fourteen distinct operations:—

1. *Straightening the wire.* The wire, as obtained from the drawing-frame, is wound about a bobbin or barrel, about 6 inches diameter, which gives it a curvature that must be removed. The straightening engine is formed by fixing 6 or 7 nails upright in a waving line on a board, so that the void space measured in a straight line between the first three nails may have exactly the thickness of the wire to be trimmed; and that the other nails may make the wire take a certain curve line, which must vary with its thickness. The workman pulls the wire with pincers through among these nails, to the length of about 30 feet, at a running draught; and after he cuts that off, he returns for as much more; he can thus finish 600 fathoms in the hour. He next cuts these long pieces into lengths of 3 or 4 pins. A day's work of one man amounts to 18 or 20 thousand dozen of pin-lengths.

2. *Pointing*, is executed on two iron or steel grindstones, by two workmen, one of whom roughens down, and the other finishes. Thirty or forty of the pin wires are applied to the grindstone at once, arranged in one plane, between the two forefingers and thumbs of both hands, which dexterously give them a rotatory movement.

3. *Cutting these wires into pin-lengths.* This is done by an adjusted chisel. The intermediate portions are handed over to the *pointer*.

4. *Twisting of the wire for the pin-heads.* These are made of a much finer wire, coiled into a compact spiral, round a wire of the size of the pins, by means of a small lathe constructed for the purpose.

5. *Cutting the heads.* Two turns are dexterously cut off for each head, by a regulated chisel. A skilful workman may turn off 12,000 in the hour.

6. *Annealing the heads.* They are put into an iron ladle, made red-hot over an open fire, and then thrown into cold water.

7. *Stamping or shaping the heads.* This is done by the blow of a small ram, raised by means of a pedal lever and a cord. The pin-heads are also fixed on by the same operative, who makes about 1,500 pins in the hour, or from 12,000 to 15,000 per diem, exclusive of one-thirteenth, which is always deducted for waste in this department, as well as in the rest of the manufacture. Cast heads, of an alloy of tin and antimony, were introduced by patent, but never came into general use.

8. *Yellowing or cleaning the pins,* is effected by boiling them for half an hour in sour beer, wine lees, or solution of tartar; after which they are washed.

9. *Whitening or tinning.* A stratum of about 6 pounds of pins is laid in a copper-pan, then a stratum of about 7 to 8 pounds of grain tin; and so alternately till the vessel be filled; a pipe being left inserted at one side, to permit the introduction of water slowly at the bottom, without deranging the contents. When the pipe is withdrawn, its space is filled up with grain tin. The vessel being now set on the fire, and the water becoming hot, its surface is sprinkled with 4 ounces of cream of tartar; after which it is allowed to boil for an hour. The pins and tin grains are, lastly, separated by a kind of cullender.

10. *Washing the pins,* in pure water.

11. *Drying and polishing them,* in a leather sack filled with coarse bran, which is agitated to and fro by two men.

12. *Winnowing,* by fanners.

13. *Pricking the papers,* for receiving the pins.

14. *Papering,* or fixing them in the paper. This is done by children, who acquire the habit of putting up 36,000 per day.

The pin manufacture is one of the greatest prodigies of the division of labour; it furnishes 12,000 articles for the sum of three shillings, which have required the united diligence of fourteen skilful operatives.

The above is an outline of the mode of manufacturing pins by hand labour; but several beautiful inventions have been employed to make them entirely, or in a great measure, by machinery; the consumption for home sale and export amounting to 15 millions daily, for this country alone. A detailed description of it will be found in the 9th volume of 'Newton's London Journal.' The following outline will give the reader an idea of the structure of Mr. L. W. Wright's ingenious machine for pin-making:—

The rotation of a principal shaft mounted with several cams gives motion to various sliders, levers, and wheels, which work the different parts. A slider pushes pincers forwards, which draw wire from a reel, at every rotation of the shaft, and advance such a length of wire as will produce one pin. A die cuts off the said length of wire by the descent of its upper chap; the chap then opens a carrier, which takes the pin to the pointing apparatus. Here it is received by a holder, which turns round, while a bevel-edged file-wheel rapidly revolves, and tapers the end of the wire to a point. The pin is now conducted by a second carrier to a finer file-wheel, in order to finish the point by a second grinding. A third carrier then transfers the pin to the first heading die, and by the advance of a steel-punch the end of the pin wire is forced into a recess, whereby the head is partially swelled out. A fourth carrier removes the pin to a second die, where the heading is perfected. When the heading-bar retires, a forked lever draws the finished pin from the die, and drops it into a receptacle below.

The following is a further detail of this very interesting manufacture:—

In pin-making the wire is brass, (a compound of copper and zinc): it is reduced by the ordinary process of wire-drawing to the requisite thickness: in this process it is necessarily curved. To remove this it is re-wound, and pulled through between a number of pins arranged at the draw or straightening bench; it is then cut into convenient lengths for removal, and finally reduced to just such a length as will make two pins. The pointing is done upon steel mills (revolving wheels), the circumference of which is cut with teeth, the one fine, the other coarse. Thirty or forty lengths are packed up at once, and, as in needle-making, the cast of hand given by the workman makes them revolve, and the whole are pointed at once; the same operation is performed with the other end. The process of heading is next performed as follows: a number of the pointed wires now cut in two, are placed in the feeder of the machine; one drops, is firmly seized, and by means of a pair of dies, a portion of the metal is forced up into a small bulb; by a beautifully simple and automatic arrangement, it is passed into another, when a small horizontal hammer gives it a sharp tap, which completes the head. The white colour is produced by boiling in a solution of cream of tartar and tin. They are then dried, and passed into the hands of the wrappers-up. The preparation for marking the paper is peculiar, and is done by means of a moulded piece of wood, the moulds corresponding to those portions which represent the small folds of paper through which the pins are passed, and thereby held. The pins are then taken to the paperers, who are each seated in front of a bench, to which is attached a horizontally-hinged piece of iron, the edge of which is notched with a corresponding number of marks to the number of pins to be stuck; the small catch which holds together the two parts of the iron is released, the paper introduced, and a pin inserted at every mark; the paper is then released, and the task of examination follows, which is the work of a moment. The paper of pins is held so that the light strikes upon it: those defective are immediately detected by the shade, are taken out, and others substituted in their stead. An ancient edict of Henry VIII. held that 'no one should sell any pins but such as were double-headed, or the heads soldered fast on.'

An improved pin has been introduced, in which iron or steel wires have been employed. The iron or steel wire employed should be very round, and, to protect it from rust, it should, at the last drawing, be lubricated by means of a sponge saturated with oil, placed between the draw-plate and reel.

The following is the process adopted with these:—The wire being cut into pins and these headed and pointed, all according to the usual methods, the pins are thrown into a revolving cylinder of wood containing a bath of soap-and-water in a hot state. It is of the capacity of about 9½ gallons, but should not contain more than about 1½ gallon of water, with about 2 ounces of soap dissolved therein, as this quantity will be sufficient for the treatment of about 13½ lbs. weight of pins at a time. The cylinder, when thus charged, is made to revolve for about a quarter of an hour; at the expiration of which time the pins are found free from the oil with which they were previously coated, and also very much smoothed and polished by their rubbing one against the other.

The pins are next dried by transferring them to another cylinder partially filled with well-dried sawdust (preferring for the purpose the sawdust of poplar wood), and causing this cylinder to revolve for about ten minutes; or, instead of employing a cylinder of this description, the pins may be thrown into a bag or bags partially filled with sawdust, and the requisite friction produced by swinging or rolling these bags about for the same length of time.

Into a glass or stone vase, there are put about 1½ gallon of salt water, $\frac{7}{10}$ths of a pound of sulphuric acid, $\frac{6}{100}$ lb. of salt of tin, $\frac{8}{100}$ lb. of crystallised sulphate of zinc, and 100 grs. of pure sulphate of copper. This mixture is left to work for about 24 hours, so that the salts and sulphates may be properly dissolved.

The mixture, prepared as directed, is introduced into another revolving cylinder, and pins about 13½ lbs. weight are thrown into the midst of it. The cylinder is then caused to revolve for about half an hour, which serves at once to remove any verdigris from the pins, to impart a high polish to them, and to give a beginning to the copper-coating process. At the end of the half hour or thereabouts, 232 grs. of crystallised sulphate of copper in coarse powder, and 150 grs. of crystallised sulphate of zinc, previously dissolved in soft water, are added to the mixture in the cylinder, and the whole again agitated for about a quarter of an hour. The pins are by this operation not only completely coated, but acquire a very considerable degree of polish. The copper liquors being drawn off, the pins are washed with cold water in the rotating cylinder, and afterwards in a tub with soap-and-water out of contact with air, where they are well shaken. The contents of the tub are then emptied into a wooden strainer, having a perforated bottom of tin-plate iron. The pins are finally dried by agitation with dry sawdust.

The tinning and blanching are performed by laying the pins upon plates of very thin tin placed one above another, in a tinned copper boiler containing a solution of about 4⅔ lbs. of crude tartar or cream of tartar, in about 22 gallons of water, and then setting the whole to boil for about 12 hours. The tartar solution should be prepared at least 24 hours previously. A little more cream of tartar improves the brilliancy of the pins.

PINUS. See PINES.

PIPECLAY. A hydrous silicate of alumina, found in Devonshire and some other parts, used in the manufacture of tobacco-pipes. See CLAY.

PIPERDINE. A volatile base, discovered by Anderson, by acting with potash on the product of the action of nitric acid on piperine. It may also be procured by treating piperine with potash. It has been chiefly studied by Cahours.

PIPERINE is a crystalline principle extracted from black pepper, by means of alcohol. It is colourless, has hardly any taste, fuses at 212° F.; is insoluble in water, but soluble in acetic acid, ether, and most readily in alcohol.

PIPESTONE. A variety of clay slate. See CATLINITE.

PISOLITE. The peastone. See LIMESTONE.

PISOLITIC IRON ORE. An ore made up of small nodules, like peas. See IRON.

PITA HEMP. The fibre of the American aloe (*Agave Americana*), used for textile fabrics, and in paper-making.

PITCHBLENDE. An ore of uranium. See URANIUM.

PITCH, MINERAL, is the same as BITUMEN and ASPHALT, which see.

PITCH *of wood-tar* (*Poix*, Fr.; *Pech*, Ger.) is obtained by boiling tar in an open iron pot, or in a still, till the volatile matters are driven off. Pitch contains pyroligneous resin along with colophony (common rosin), but its principal ingredient is the former, called by Berzelius *pyretine*. It is brittle in the cold, but softens and becomes ductile with heat. See TAR.

PITCHSTONE. A volcanic rock resembling obsidian, but having a pitchy rather than a glassy lustre.

PIT-COAL. See COAL.

PITTACAL, from two Greek words, signifying *fine pitch*, is one of the principles detected in wood-tar by Reichenbach. It is obtained by adding baryta-water to a solution of *picamar*, or of oil of tar deprived of its acid, when the pittacal falls. It is a dark blue solid substance, somewhat like indigo, and assumes a metallic lustre on friction. It is void of taste and smell, not volatile; carbonises at a high heat without emitting an ammoniacal smell; is soluble or rather very diffusable in water; gives a green solution, with a cast of crimson, in sulphuric acid, with a cast of red-blue in muriatic acid, and with a cast of aurora-red in acetic acid. It is insoluble in alkalis, and in alcohol and ether. It dyes a fast blue upon linen and cotton goods with tin and aluminous mordants.

PLAGIOCLASE. See FELSPAR.

PLANE TREE. The *Platanus occidentalis*, one of the largest of the American trees. The wood of the plane tree is much used for quays; it is also employed for musical instruments, and for other works requiring a clean light-coloured wood. The False Plane, or Sycamore, is one of the Maple family (*Acer pseudo-platanus*).

PLANTAIN. See BANANA.

PLASMA. A translucent chalcedony, of a greenish colour and a glittering lustre.

PLASTER. See MORTAR.

PLASTER OF PARIS. See ALABASTER and GYPSUM.

PLASTIC CLAY. Any clay which, when in a moist state, may be kneaded between the fingers, and admits of being moulded into a definite form.

Plastic clay is not confined to any particular strata, but is found in secondary and tertiary formations, and also in deposits derived from the decomposition of other rocks. In geological nomenclature, however, the term Plastic Clay is applied to those portions of the Lower Tertiary or Eocene strata which intervene between the Chalk and the London clay, in consequence of some of the beds of clay of which they are composed being of a plastic nature. Some of the earliest pottery made in the country was manufactured from these clays, dug up at Crendle Common, near Cranborne, in Dorsetshire, where, as well as at Newport in the Isle of Wight, Fareham in Hants, &c., the clay is still dug and converted into pottery. The clay from the Plastic Clay series is generally of a bright brick-red colour, frequently mottled with white, but sometimes (as at Crendle) it is dark purple or nearly black towards the lower part, and this clay is said to be the best as regards quality. The clays of the Plastic Clay burn to a red colour, and are manufactured into bricks, tiles, flower-pots, and other coarse pottery.—H. W. B.

The Plastic Clay series, between the Thanet Sand and the London Clay, is now generally known by Mr. Prestwich's name of the Woolwich and Reading beds.

PLATE-CLEANING. Boil 30 grms. of finely-powdered and calcined hartshorn in a quart of water, and while on the fire put as many silver articles in the vessels used for boiling as it will hold, and leave them there for a short time; then withdraw them, and dry them over the fire; continue this until all the articles have been treated in the same manner; then introduce into the hartshorn-water clean woollen rags, and allow them to remain until saturated, after which dry them, and use them for polishing the silver. This is also the best substance for cleaning locks and brass handles of room-doors. When the silver articles are perfectly dry, they must be carefully rubbed with a soft leather. This mode of cleaning is excellent, and much preferable to the employment of any powder containing mercury, as mercury has the effect of rendering the silver so brittle as to break on falling.

PLATE GLASS. See GLASS.

PLATED MANUFACTURE. (*Fabrique de plaqué*, Fr.; *Silber Plattirung*, Ger.) The silver in this case is not applied to ingots of pure copper, but to an alloy consisting of copper and brass, which possesses the requisite stiffness for the various articles.

The furnace used for melting that alloy, in black-lead crucibles, is a common air-furnace, like that for making brass. See Brass.

The ingot-moulds are made of cast iron, in two pieces, fastened together; the cavity being of a rectangular shape, 3 inches broad, 1¼ thick, and 18 or 20 long. There is an elevated mouth-piece or gate, to give pressure to the liquid metal, and secure solidity to the ingot. The mould is heated till the grease with which its cavity is besmeared merely begins to smoke, but does not burn. The proper heat of the melted metal for casting, is when it assumes a bluish colour, and is quite liquid. Whenever the metal has solidified in the mould, the wedges that tighten its rings are driven out, lest the shrinkage of the ingot should cause the mould to crack.

The ingot is now dressed carefully with the file on one or two faces, according as it is to be single- or double-plated. The thickness of the silver plate is such as to constitute one fortieth of the thickness of the ingot; or when this is an inch and a quarter thick, the silver plate applied in one thirty-second of an inch; being by weight a pound troy of the former, to from 8 to 10 pennyweights of the latter. The silver, which is slightly less in size than the copper, is tied to it truly with iron wire, and a little of a saturated solution of borax is then insinuated at the edges. This salt melts at a low heat, and excludes the atmosphere, which might oxidise the copper, and obstruct the union of the metals. The ingot thus prepared is brought to the plating furnace.

The furnace has an iron door with a small hole to look through; it is fed with coke laid upon a grate at a level with the bottom of the door. The ingot is placed immediately upon the coke, the door is shut, and the plater watches at the peep-hole the instant when the proper soldering-temperature is attained. During the union of the silver and copper, the surface of the former is seen to be drawn into intimate contact with the latter, and this species of *riveting* is the signal for removing the compound bar instantly from the furnace. Were it to remain a very little longer, the silver would become alloyed with the copper, and the plating be thus completely spoiled. The adhesion is, in fact, accomplished here by the formation of a film of true silver-solder at the surfaces of contact.

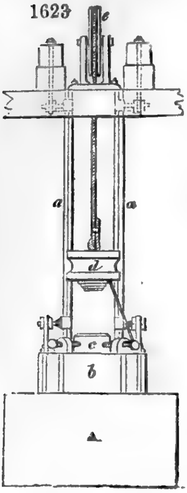
The ingot is next cleaned, and rolled to the proper thinness between cylinders, as described under Mint; being in its progress of lamination frequently annealed on a small reverberatory hearth. After the last annealing, the sheets are immersed in hot dilute sulphuric acid, and scoured with fine Calais sand; they are then ready to be fashioned into various articles.

In plating copper-wire, the silver is first formed into a tubular shape, with one edge projecting slightly over the other; through which a red-hot copper cylinder being somewhat loosely run, the silver edges are closely pressed together with a steel burnisher, whereby they get firmly united. The tube thus completed is cleaned inside, and put on the proper copper rod, which it exactly fits. The copper is left a little longer than its coating tube, and is grooved at the extremities of the latter, so that the silver edges, being worked into the copper groove, may exclude the air from the surface of the rod. The compound cylinder is now heated red-hot, and rubbed briskly over with the steel burnisher in a longitudinal direction, whereby the two metals get firmly united, and form a solid rod, ready to be drawn into wire of any requisite fineness and form; as flat, half-round, fluted, or with mouldings, according to the figure of the hole in the draw-plate. Such wire is much used for making bread-baskets, toast-racks, snuffers, and articles combining elegance with lightness and economy. The wire must be annealed from time to time during the drawing, and finally cleaned, like the plates, with dilute acid.

Formerly the different-shaped vessels of plated metal were all fashioned by the hammer; but every one of simple form is now made in dies struck with a drop-hammer or stamp. Some manufacturers employ 8 or 10 drop machines.

Figs. 1623 and 1624 are two views of the stamp: A is a large stone, the more massy the better; *b*, the anvil on which the die, *c*, is secured by four screws, as shown in the ground plan, *fig.* 1625. In *fig.* 1623, *a a* are two upright square prisms, set diagonally with the angles opposed to each other; between which the hammer or drop, *d*, slides truly, by means of nicely-fitted angular grooves or recesses in its sides. The hammer is raised by pulling the rope, *f*, which passes over the pulley, *e*, and is let fall from different heights, according to the impulse required. Vessels which are less in diameter at the top and bottom than in the middle, must either be raised by the stamp in two pieces, or raised by a hand-hammer. The die is usually made of *cast* steel. When it is placed upon the anvil, and the plated metal is cut into pieces of proper size, the top of the die is then surrounded with a lute, made of oil and clay, for an inch or two above its surface; and the cavity is filled with melted lead. The under face of the stamp-hammer has a plate of iron, called the *licker-up*, fitted into it, about the area of the die. Whenever the lead has become solid, the hammer is raised to a certain height, and dropped down upon it; and as the under face of the licker-up is made rough like a rasp, it firmly adheres to the lead, so as to lift it afterwards with the hammer. The plated metal is now placed over the die, and the hammer, mounted with its lead, is let fall repeatedly upon it, till the impression on the metal is complete. If the vessel to be struck be of any considerable depth, two or three dies may be used of progressive sizes in succession. But it occasionally happens that when the vessel has a long conical neck, recourse must be had to an auxiliary operation, called *punching*. See the embossing punches, *fig.* 1626. These are made of cast steel, with their hollows turned out in the lathe. The pieces, *a b*, are of lead. The punching is performed by a series of these tools, of different sizes, beginning with the largest, and ending with the least. By this means a hollow cone, 3 or 4 inches deep, and 1 inch in diameter, may be raised out of a flat plate. These punches are struck with a hand-hammer also, for small articles of too great delicacy for the drop. Indeed, it frequently happens that one part of an article is executed by the stamp and another by the hand.

1623



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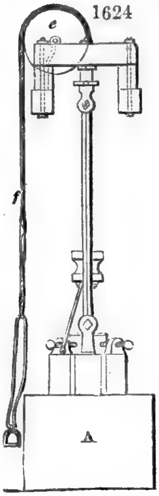

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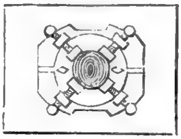

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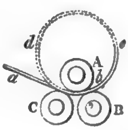

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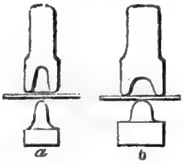
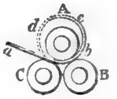


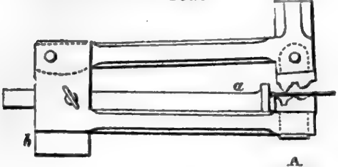
1627



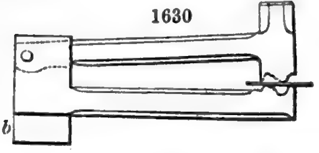
Cylindrical and conical vessels are mostly formed by bending and soldering. The bending is performed on blocks of wood, with wooden mallets; but the machine so much used by the tin-smiths, to form their tubes and cylindric vessels (see the end sections, *figs.* 1627, 1628), might be employed with advantage. This consists of 3 iron rollers fixed in an iron frame. A, B, C, are the three cylinders, and *a*, *b*, *c*, *d*, the riband or sheet of metal passed through them to receive the cylindrical or conical curvature. The upper roller, A, can be raised or lowered at pleasure, in order to modify the diameter of the tube; and when one end of the roller is higher than the other the conical curvature is given. The edges of the plated cylinders or cones are soldered with an alloy composed of silver and brass. An alloy of silver and copper is somewhat more fusible; but that of brass and silver answers best for plated metal, the brass being in very small proportion, lest the colour of the plate be affected. Calcined borax mixed with sandiver (the salt skimmed from the pots of crown glass) is used along with the alloy, in the act of soldering. The seam of the plated metal being smeared with that saline mixture made into a pap with water, and the bits of laminated solder, cut small with scissors, laid on, the seam is exposed to the flame of an oil blowpipe, or to that of charcoal urged by bellows in a little forge-hearth, till the solder melts and flows evenly along the junction. The use of the sandiver seems to be to prevent the iron wire that binds the plated metal tube from being soldered to it.

Mouldings are sometimes formed upon the edges of vessels, which are not merely ornamental, but give strength and stiffness. These are fashioned by an instrument called a *swage*, represented in *figs.* 1629, 1630. The part A lifts up by a joint, and the metal to be *swaged* is placed between the dies, as shown in the figures; the tail, *b*, being held in the jaws of a vice, while the shear-shaped hammer rests upon it. By striking on the head, A, while the metal plate is shifted successively forwards, the beading is formed. In *fig.* 1629, the tooth, *a*, is a guide to regulate the distance between the bead and the edge. A similar effect is produced of late years in a neater and more expeditious manner by the rollers, *figs.* 1631, 1633. *Fig.* 1632 is a section to show the form of the bead. The two wheels *a*, *a*, *fig.* 1631, are placed upon axes, two of which are furnished with toothed pinions in their middle; the lower one being turned by the handle, gives motion to the upper. The groove in the upper wheel corresponds with the bead in the lower, so that the slip of metal passed through between them assumes the same figure.

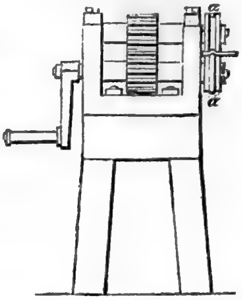
1629



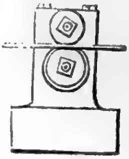
1630



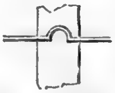
1631



1633



1632



The greatest improvement made in this branch of manufacture is the introduction of silver edges, beads, and mouldings, instead of the plated ones, which from their prominence had their silver surface speedily worn off, and thus assumed a brassy look. The silver destined to form the ornamental edging is laminated exceedingly thin; a square inch sometimes weighing no more than 10 or 12 grains. This is too fragile to bear the action of the opposite steel dies of the swage above described. It is necessary, therefore, that the sunk part of the die should be steel, and the opposite side lead, as was observed in the stamping; and this is the method now generally employed to form these silver ornaments. The inside shell of this silver moulding is filled with soft solder, and then bent into the requisite form.

The base of candlesticks is generally made in a die by the stamp, as well as the neck, the dish part of the nozzle or socket, and the tubular stem or pillar. The different parts are united, some with soft and others with hard solder. The branches of candlesticks are formed in two semi-cylindrical halves, like the feet of tea-urns. When an article is to be engraved on, an extra plate of silver is applied at the proper part, while the plate is still flat, and fixed by burnishing with great pressure over a hot anvil. This is a species of welding.

The last finish of plated goods is given by burnishing tools of bloodstone, fixed in sheet-iron cases, or hardened steel, finely polished.

The ingots for lamination might probably be plated with advantage by the delicate pressure process employed for silvering copper-wire.

For the processes of Electro-plating, see ELECTRO-METALLURGY.

PLATINUM (*Sym.* Pt., *At. wt.* 98·5). A metal of a greyish-white colour, harder than silver, and of about double its density, being of specific gravity 21. It is so infusible, that no considerable portion of it can be melted by the strongest heats of our furnaces. It is unchangeable in the air and water; nor does a white heat impair its polish. The only acid which dissolves it is the nitro-muriatic.

Native Platinum in the natural state is never pure, being alloyed with several other metals. It occurs only under the form of grains, which are usually flattened, and resemble in shape the gold *pepitas*. Their size is in general less than linseed, although in some cases they equal hemp-seed, and, occasionally, peas. One piece brought from Choco, in Peru, and presented to the Cabinet of Berlin by M. Humboldt, weighs 882½ grains, or more than 2 oz. avoirdupois. A lump of native platinum is in the Royal Museum of Madrid, which was found in 1814 in the gold mine of Condoto, province of Novita, at Choco. Its size is greater than a turkey's egg (about 2 inches one diameter, and 4 inches the other), and its weight 11,641 grains. In 1827 a specimen was found in the Ural Mountains which weighed 11·57 pounds troy; the largest yet obtained being in the Demidoff Cabinet, and weighing 21 pounds.

The colour of the grains of native platinum is generally a greyish white, like tarnished steel. The cavities of the rough grains are often filled with earthy and ferruginous matters, or sometimes with small grains of magnetic oxide of iron, adhering to the surface of the platinum grains. Their specific gravity is also much lower than that of forged pure platinum; varying from 15 in the small particles, to 18·94 in Humboldt's large specimen. This relative likeness is owing to the presence of iron, copper, lead, and chromium, besides its other metallic constituents, palladium, osmium, rhodium, and iridium.

Its main localities in the New Continent are the three following districts:—

At Choco, in the neighbourhood of Barbacoas, and generally on the coasts of the South Sea, or on the western slopes of the Cordillera of the Andes, between the 2nd and the 6th degrees of north latitude. The gold-washings that furnish most platinum are those of Condoto, in the province of Novita; those of Santa Rita, or Viroviro, of Santa Lucia, of the ravine of Iro, and Apoto, between Novita and Taddo. The deposit of gold and platinum grains is found in alluvial ground, at a depth of about 20 feet. The gold is separated from the platinum by picking with the hand, and also by amalgamation; formerly, when it was imagined that platinum might be used to debase gold, the grains of the former metal were thrown into the rivers, through which mistaken opinion an immense quantity of it was lost.

Platinum grains are found in Brazil, but always in the alluvial lands that contain gold, particularly in those of Matto-Grosso. The ore of this country is somewhat different from that of Choco. It is in grains, which seem to be fragments of a spongy substance. All the particles are nearly globular, exhibiting a surface formed of small spheroidal protuberances strongly cohering together, whose interstices are clean, and even brilliant. This platinum includes many small particles of gold, but none of the magnetic iron-sand or of the small zircons which accompany the Peruvian ore. It is mixed with small grains of native palladium, which may be recognised by their fibrous or radiated structure and particularly by their chemical characters.

Platinum grains are found in Hayti, or Saint Domingo, in the sand of the river Jacky, near the mountains of Sibao. Like those of Choco, they are in small brilliant grains, as if polished by friction. The sand containing them is quartzose and ferruginous. This native platinum contains, like that of Choco, chromium, copper, osmium, iridium, rhodium, palladium, and probably titanium. Vauquelin could find no gold among the grains.

Platinum is largely produced in the Russian territories, in the auriferous sands of Kuschwa, 250 wersts from Ekaterinbourg, and consequently in a geological position which seems to be analogous to that of South America. It also occurs at Nischne-Tagilsk and Goroblagodat, in the Ural, in alluvial and drift material.

These auriferous sands are, indeed, almost all superficial; they cover an argillaceous soil, and include, along with gold and platinum, *débris* of dolerite (a kind of basalt) magnetic iron-ore, grains of corundum, &c. The platinum grains are not so flat as those from Choco, but they are thicker; they have less brilliancy, and more of a leaden hue. This platinum, by M. Laugier's analysis, is similar in purity to that cf Choco; but the leaden-grey grains, which were taken for a mixture of osmium and iridium, are merely an alloy of platinum, containing 25 per cent. of these metals. In Russia platinum has been formed into coins of eleven and twenty-two roubles each; and this country affords annually about 800 cwts. of platinum, which is nearly ten times the amount from other parts of the world.

Platinum has also been found in Borneo, in California, in North Carolina, in Canada, in Australia, in the sands of the Rhine, and in Co. Wicklow, Ireland.

M. Vauquelin found nearly 10 per cent. of platinum in an ore of argentiferous copper, which was transmitted to him as coming from Guadalcanal, in Spain. This would be the only example of platinum existing in a rock and in a vein. The same thing has not again been met with, even in other specimens from Guadalcanal.

Platinum has been known in Europe only since 1748, though it was noticed by Ulloa in 1741. It was compared at first to gold; and was, in fact, brought into the market under the name of white gold. The term 'platinum,' however, is derived from the Spanish word *plata*, silver, on account of its resemblance in colour to that metal.

The whole of the platinum ore from the Urals is sent to St. Petersburg, where it is, or formerly was, treated by the following simple process:—

One part of the ore is put into open platina vessels, capable of containing from 6 to 8 lbs., along with 3 parts of muriatic acid at 25° B. and 1 part of nitric acid at 40°. Thirty of these vessels are placed upon a sand-bath covered with a glazed dome with moveable panes, which is surmounted by a ventilating chimney to carry the vapours out of the laboratory. Heat is applied for 8 or 10 hours, till no more red vapours appear: a proof that the whole nitric acid is decomposed, though some of the muriatic remains. After settling the supernatant liquid is decanted off into large cylindrical glass vessels, the residuum is washed, and the washing is also decanted off. A fresh quantity of nitro-muriatic acid is now poured upon the residuum. This treatment is repeated till the whole solid matter has eventually disappeared. The ore requires for solution from 10 to 15 times its weight of nitro-muriatic acid, according to the size of its grains.

The solutions thus made are all acid: a circumstance essential to prevent the iridium from precipitating with the platinum, by the water of ammonia, which is next added. The deposit being allowed to form, the mother-waters are poured off; the precipitate is washed with cold water, dried, and calcined in crucibles of platinum.

The mother-waters and the washings are afterwards treated separately; the former being concentrated to one-twelfth of their bulk in glass retorts; on cooling, they let fall the iridium in the state of an ammoniacal chloride, constituting a dark purple powder, occasionally crystallised in regular octahedrons. The washings are evaporated to dryness in porcelain vessels; the residuum is calcined and treated like fresh ore; but the platinum it affords needs a second purification.

For agglomerating the platinum, the spongy mass is pounded in bronze mortars; the powder is passed through a fine sieve, and put into a cylinder of the intended size of the ingot. The cylinder is fitted with a rammer, which is forced in by a coining press, till the powder is much condensed. It is then turned out of the mould, and baked 36 hours in a porcelain kiln, after which it may be readily forged, if it be pure, and may receive any desired form from the hammer. It contracts in volume from 1-6th to 1-5th during the calcination.

The method ordinarily used for the extraction of platinum is that originally proposed by Dr. Wollaston. The ore is treated first with nitric and then with hydrochloric acid, to remove those metals which are readily soluble, and is afterwards digested in dilute aqua regia at a moderate heat. To the solution of platinum thus obtained, a solution of sal-ammoniac is added, when the platinum is precipitated in the form of a yellow salt—the double chloride of platinum and ammonium. This salt, when washed, is heated to redness, whereby the chlorine and ammonia are expelled, whilst a mass of *spongy platinum* is obtained. The sponge is worked into a paste with water, and, having been subjected to powerful pressure and dried, is carefully heated to whiteness in a wind-furnace and forged into an ingot. The platinum at a high temperature may be welded like iron.

For Dr. Wollaston's process, see *Philosophical Transactions*, 1829, Part I.

Great improvements in refining platinum have been introduced by Messrs. Deville and Debray. In a furnace, composed of blocks of lime, the platinum is fused by means of the oxyhydrogen flame, when the osmium present is expelled as tetroxide, while the silica forms a slag by combining with the lime.

The same chemists effect the purification of platinum by fusing the ore with galena in a reverberatory furnace. The metallic lead from the galena alloys with the platinum, whilst the iridosmine present in the ore is unattacked, and sinks, by its great density, to the bottom of the bath. The alloy of lead and platinum is then drawn off, and the lead removed by cupellation.

Platinum furnishes most valuable vessels to both analytical and manufacturing chemists. Boilers and stills of platinum used in the manufacture of oil of vitriol are constructed of large size and at great cost. The metal is malleable, and may be beaten out into leaves of extreme thinness. Dr. Wollaston succeeded in obtaining a wire not exceeding the two-thousandth of an inch in diameter. A wire of this metal of $\frac{1}{18}$th inch in diameter will support a weight of 361 lbs.

In 1828 a platinum coinage was commenced in Russia, but was discontinued in 1845.

This metal is applied to porcelain by two different processes: sometimes in a rather coarse powder, applied by the brush, like gold, to form ornamental figures; sometimes in a state of extreme division, obtained by decomposing its nitro-muriatic solution, by means of an essential oil, such as rosemary or lavender. In this case, it must be evenly spread over the whole ground. Both modes of application give rise to a steely lustre.

The properties possessed in common by gold and platinum have several times given occasion to fraudulent admixtures, which have deceived the assayers. M. Vauquelin having executed a series of experiments to elucidate this subject, drew the following conclusions:—

If the platinum do not exceed 30 or 40 parts in the thousand of the alloy, the gold does not retain any of it when the parting is made with nitric acid in the usual way; and when the proportion of platinum is greater, the fraud becomes manifest, 1st, by the higher temperature required to pass it through the cupel, and to form a round button; 2nd, by the absence of the lightning, fulguration, or coruscation; 3rd, by the dull white colour of the button and its crystallised surface; 4th, by the straw-yellow colour which platinum communicates to the aquafortis in the parting; 5th, by the straw-yellow colour, bordering on white, of the cornet after it is annealed. If the platinum amounts to one fourth of the gold, we must add to the alloy at least 3 times its weight of fine silver, laminate it very thin, anneal somewhat strongly, boil it half an hour in the first aquafortis, and at least a quarter of an hour in the second, in order that the acid may dissolve the whole of the platinum.

Were it required to determine exactly the proportions of platinum contained in an alloy of copper, silver, gold, and platinum, the amount of the copper may be found in the first place by *cupellation*; then the respective quantities of the three other metals may be learned by the processes founded, 1, upon the property possessed by sulphuric acid of dissolving silver without affecting gold or platinum; and, 2, upon the property of platinum being soluble in nitric acid, when it is alloyed with a certain quantity of gold and silver.

Platina, wrought and unwrought, imported in 1873.

	Ounces troy	Value
From Russia	39,284	£51,642
„ Germany	11,540	11,542
„ Other countries	6,157	9,580
Total	56,981	72,764

PLATINUM, ALLOYS OF. This metal will alloy with iron; the alloy is malleable and possesses much lustre. Copper and platinum in certain proportions form a brilliant alloy. Silver is much hardened by platinum: although platinum is not soluble in nitric acid, it will, when alloyed with silver, dissolve in that acid. An alloy of platinum and iridium is harder than platinum, and withstands the action of nitro-hydrochloric acid.

Some other alloys are known, but none of them are employed in the arts.

PLATINUM BLACK. This interesting preparation, which so rapidly oxidises alcohol into acetic acid, &c., by what has been called catalytic or contact action, is most easily prepared by the following process devised by M. Bœttger:—The insoluble powder of potassio-chloride or ammonio-chloride of platinum is to be moistened with sulphuric acid (oil of vitriol), and a bit of zinc is to be laid in the mixture. The platinum becomes reduced to a black powder, which is to be washed first with hydrochloric acid, and then with water. The fineness of this powder depends upon that of the saline powders employed to make it; so that if these be previously finely ground, the platinum black will be also very fine, and proportionally powerful as a chemical agent.

The following method of preparing igniferous black platinum, proposed by Descotil, has been recommended by M. Döbereiner:—

Melt platinum ore with double its weight of zinc; reduce the alloy to powder, and treat it first with dilute sulphuric acid, and next with dilute nitric acid, to oxidise and dissolve out all the zinc, which is somewhat difficult to do, even at a boiling-heat. The insoluble black-grey powder contains some osmide of iridium, united with the crude platinum. This compound acts like simple platinum black, after it has been purified by digestion in potash-lye, and washing with water. Its oxidising power is so great as to transform not only formic acid into the carbonic, and alcohol into vinegar, but even some osmic acid, from the metallic osmium. The above powder explodes by heat like gunpowder.

When the platinum black prepared by means of zinc is moistened with alcohol, it becomes incandescent, and emits osmic acid; but if it be mixed with alcohol into a paste and spread upon a watch-glass, nothing but acetic acid will be disengaged; affording an elegant means of diffusing the odour of vinegar in an apartment.

A yet more simple method of preparing the platinum black than either of those is the following:—Protochloride of platinum is dissolved in a concentrated solution of potash with the aid of heat; then alcohol is added by degrees, constantly stirring the solution. The platinum is precipitated as a black powder, which is boiled successively with alcohol, hydrochloric acid, and potash-water.

PLATINUM, FULMINATING. An explosive compound, obtained by adding acetic acid, in excess, to a solution of chloride of platinum and ammonium in caustic soda. It may also be prepared by precipitating sulphate of platinum with excess of ammonia.

PLATINUM, SALTS OF. The salts of platinum being rarely employed in the arts or manufactures, the reader is referred for them to Watts's 'Dictionary of Chemistry.'

PLATINUM, SPONGY. A loose porous form of metallic platinum, obtained by heating the double chloride of platinum and ammonium.

PLATINUM YELLOW. A pigment prepared from platinum, by oxidation with acids, is sold under this name.

PLUMBAGO, commonly called Black Lead; the name *plumbago*, and its common one, being derived from the fact of this mineral resembling lead in its external appearance. See GRAPHITE, for its mineralogical and chemical characters. In this country plumbago has been found most abundantly in Cumberland. The mountain at Borrowdale, in which the black lead is mined, is nearly 2,000 feet high, and the entrance to the mine is about 1,000 feet below its summit. This valuable mineral became so common a subject of robbery about a century ago, as to have enriched, it was said, a great many persons living in the neighbourhood. Even the guard stationed over it by the proprietors was of little avail against men infuriated with the love of plunder; since in those days a body of miners broke into the mine by main force, and held possession of it for a considerable time.

The treasure was then protected by a building, consisting of four rooms upon the ground-floor; and immediately under one of them is the opening, secured by a trap-door, through which alone workmen could enter the interior of the mountain. In this apartment, called the dressing-room, the miners change their ordinary clothes for their mining-dress. At one time as much as 100,000*l.* was realised from the Borrowdale mine in a year, the Cumberland plumbago selling at 45*s.* per pound. This mine has not, however, been worked for many years. The last great discovery, stated to have been about 30,000*l.*'s worth, has been hoarded by the proprietors, a small quantity only being sold every year; but it is now generally understood to be exhausted. Some few years since the Borrowdale Black Lead Mine was inspected by three experienced miners, but their report was far from encouraging: notwithstanding this, a new company is formed to work the mine (1874); they have found small quantities of plumbago, and the report is that the appearances are very promising.

This plumbago in Borrowdale is found in 'nests' in a trap rock, partially decomposed, which runs through the clay-slate. In Glenstrathfarrar in Inverness it is found in gneiss; and at Craigman in Ayrshire it occurs in coal-beds which have been formed in contact with trap. In Cornwall plumbago has been discovered in small lumps in the Elvan courses (see ELVAN); and on the northern coast of that county, small pieces are picked out of the clay-slate rocks, where it has been exposed by the wearing-down of the cliffs. At Arendal, in Norway, it occurs with quartz.

Plumbago occurs in Finland. Large quantities are brought from Ceylon and the East Indies. Some considerable portions are obtained from Canada.

Plumbago is sometimes formed in considerable quantities in the beds of blast furnaces, especially at Cleator Moor, and is known to the workmen as 'kish.'

Mr. Brodie purifies plumbago by mixing it in coarse powder, in an iron vessel, with twice its own weight of commercial sulphuric acid, and seven per cent. of chlorate of potash, and heats the whole over a water-bath until chloric oxide ceases to be evolved. By this means the compounds of iron, lime, and alumina present are rendered for the most part soluble, and the subsequent addition of a little fluoride of sodium to the acid mixture will decompose any silicates which may remain, and volatilise the silica present. The mass is now washed with abundance of water, dried, and heated to redness. This last operation causes the grains of the plumbago to exfoliate. The mass swells up in a surprising manner, and is reduced to a state of very minute division. It is then levigated, and obtained in a state of great purity, ready to be compressed by the method of Brockedon. See PENCILS.

Plumbago imported in 1873.

	Tons	Value
From Germany	2,009	£28,964
„ Holland	662	11,390
„ Ceylon	2,500	45,221
„ Other Countries	297	7,043
Total	5,488	£92,618

PLUSH (*Panne, Peluche,* Fr.; *Wollsammet, Plüsch,* Ger.) is a textile fabric, having a sort of velvet nap or shag upon one side. It is composed regularly of a woof of a single woollen thread, and a two-fold warp, the one, wool of two threads twisted, the other, goat's- or camel's-hair. There are also several sorts of plush made entirely of worsted. It is manufactured, like velvet, in a loom with three treadles; two of which separate and depress the woollen warp, and the third raises the hair-warp, whereupon the weaver, throwing the shuttle, passes the woof between the woollen and hair-warp; afterwards, laying a brass brooch or needle under that of the hair, he cuts it with a knife (see FUSTIAN) destined for that use, running its fine slender point along in the hollow of the guide brooch, to the end of a piece extended upon a table.

POAKE. A name amongst peltmongers for the collected waste arising in the preparation of skins: it is used for manure.

POIL DE CACHEMIRE. See ANGORA; CASHMERE.

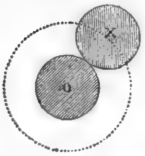
POINT NET is a style of lace formerly much in vogue, but now superseded by the bobbin net manufacture.

POLARISATION OF LIGHT. It is not the purpose of the present work to deal with any of the peculiar phenomena of the physical powers, except so far as they are involved in any of the processes of manufacture. Polarised light is employed in the sugar refinery; it therefore is necessary that some short account should be given of the phenomena so called, and of the methods of rendering them available to useful ends.

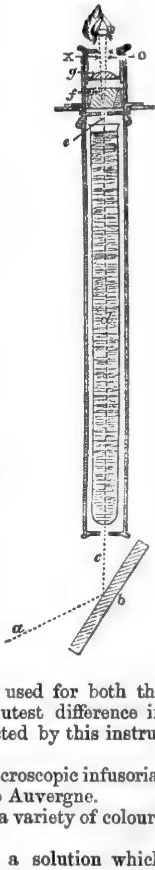
Under the term *Polarisation of Light* is comprehended a variety of very singular phenomena, which it is exceedingly difficult to explain within the space which can be devoted to this article. For anything like an exact description of these peculiar and striking phenomena, the reader is referred to works devoted specially to this branch of science. For our purpose it will be sufficient to state that if a ray of light is reflected from a plate of glass placed at an angle of about 56°, it will be found to have undergone a remarkable change. If the reflected ray of light is looked at through a thin slice of *Tourmaline*, it will be found that while the ray is seen, when the reflecting plate is in one position, it can no longer be seen through the transparent crystal if the glass-plate is turned round 90°, or if the crystal is turned to the same extent; although an ordinary ray of light is seen with equal intensity in whatever position the crystal may be held.

The ray of light by reflection, at or about the above-named angle, appears to have assumed the position of a polar body, *i.e.*, a body having dissimilar sides, or it may be, that the mode of motion has been altered by the reflection at the polarising angle. Light can be polarised by refraction equally as well as by reflection.

1635



1634



Under some circumstances, the condition of *Circular Polarisation* is produced. (See Pereira's *Lectures on Polarised Light.*) We do not attempt to explain this. The phenomena alone are all we have now to deal with. An instrument called a *Polariscope* is constructed upon the principles shown in the accompanying figure (*fig.* 1634).

If a ray of common light, *a*, be polarised by falling upon a glass, *b*, at an angle of 56° 45″, the plane-polarised ray *c*, is obtained. If this ray is transmitted through a pure solution of crystallisable cane-sugar, and the ray as it emerges, *e*, be analysed by a double-refracting rhomb of Iceland spar, *f*, two coloured images are perceived, as shown in *fig.* 1635. One, *o*, is caused by ordinary refraction, and the other, *x*, by extraordinary refraction. *g* (*fig.* 1634) is a lens to produce a well-defined image. The colours of these images are complementary; that is, when one is *red* the other is *green*, when one is *yellow* the other is *violet*, when one is *blue* the other is *orange*. By rotating the 'analyser,'—the rhomb of Iceland spar,—the colours change. If the rotation be right-handed, that is, as we turn a screw or cork-screw to make it enter, the sequence of colours is *red, orange, yellow, green, blue, indigo*, and *violet, red*. It will be understood that by rotating the rhomb of Iceland spar, the extraordinary ray revolves around the ordinary ray, each undergoing a change of colour. The sequence of the ordinary image being given above, and the complementary colours named, it will be seen that the sequence of colours on the extraordinary image will be *green, blue, indigo*, and *violet, red, orange, yellow, green*. In one complete revolution of the analyser each of the colours of the spectrum occurs twice for each image. The polariscope is now used for both the qualitative and quantitative analysis of sugar. Indeed, the minutest difference in chemical character and physical constitution can be readily detected by this instrument. See Sugar.

POLISHING-SLATE. A grey or yellow slate composed of microscopic infusoria. It is found abundantly in the coal-measures of Bohemia, and in the Auvergne.

POLYCHROMATE. (*Æsculine.*) A compound from which a variety of colours may be prepared.

A great many vegetables give, when treated with hot water, a solution which appears yellow by transmitted light, but blue by reflected light. The inner bark of the horse-chestnut is a peculiar example of this. See Fluorescence.

POLYHALITE. A sulphate of potash, lime, and magnesia, occurring in many salt mines, as at Stassfurt in Prussian Saxony.

POLYTYPE. A polytype is a cast of a woodcut taken in soft metal by a process now nearly discarded in favour of electrotyping.

POMADE DIVINE. See Balsam of Peru.

POOLEY MUNGU. Another name for Musta-paat (*Hibiscus cannabinus.*)

POPLAR. (*Peuplier*, Fr.; *Pappel*, Ger.) The wooden polishing wheels of the glass-grinder are made from horizontal sections of the stem of this tree. It is used in the manufacture of toys, but not for many other purposes.

POPLIN. A stuff made of silk and worsted, manufactured in Ireland. The Irish poplins are either watered, brocaded, or tissued: poplins are also made at Norwich.

POPPY OIL. Much used in painting. See Oils.

PORCELAIN. See Pottery.

PORCELAIN CLAY. See Clay.

PORCELAIN JASPER. Clay which has been vitrefied by the igneous rocks.

PORCELLANOUS SHELLS. See Shells.

PORPEZITE. A native alloy of gold and palladium, which occurs to some extent in the mines of Gongo Soco in Brazil.

PORPOISE OIL. See Oils.

PORPORINO. An Italian glass.

PORTER is a malt liquor, so called from being for a long period the favourite beverage of the porters of London, and indeed confined exclusively to this class of the workpeople of the metropolis. It is characterised by its dark brown colour, its transparency, its moderately bitter taste, and peculiar aromatic flavour. At first the essential distinction of porter arose from its wort being made with highly-kilned brown malt, while other kinds of beer and ale were brewed from a paler article; but of late years, the taste of the public having run in favour of sweeter and lighter beverages, the actual porter is brewed with a less proportion of brown malt, is less strongly hopped, and not allowed to get hard by long keeping in huge ripening tuns. Some brewers colour the porter with burnt sugar; but in general the most respectable concentrate a quantity of their first and best wort to an extract, in an iron pan, and burn this into a *colouring* stuff, whereby they can lay claim to the merit of using nothing in their manufacture but malt and hops. Porter is now brewed in large quantities in other cities besides London, especially in Dublin. See Beer.

PORTLAND ARROWROOT. See Arrowroot.

PORTLAND CEMENT is so called because it resembles in colour the Portland stone. It is prepared by calcining a mixture of the clayey mud of the Thames with a proper proportion of chalk. They make equally good cement in other parts of England and France by mixing chalk or marl with other clays. The materials are reduced to fine powder, and intimately mixed, with the addition of water. The resulting paste is moulded into bricks, which are dried and burned. It is of importance that the heat in calcining be sufficiently elevated, otherwise the carbonic acid and water may be expelled, without that reaction between the lime and clay which is required for the production of a cement. It is necessary to employ a white heat, which shall agglutinate and frit the mixture. After this operation the material is assorted, and the portions which are scorified by too much heat, as well as those insufficiently calcined, being set aside, the cement is pulverised for use. It is often advantageous to grind to powder the native mixtures of limestone and clay before burning them, in order to ensure homogeneousness. It will also be seen that calcination at a very high temperature is frequently required to develop the hydraulic character of limestones; the greater the temperature employed, the more slow is the solidification of the cement, but the harder does it become. See Cements.

PORTLAND STONE. An oolitic limestone, immediately underlying the Purbeck strata; so called in consequence of its development in the island of Portland, situated off the southern coast of Dorsetshire.

St. Paul's Cathedral, and many of the public buildings of this country, have been built of stone from Portland, and it is still obtained from numerous quarries on the island for transmission to other places, and formerly for the breakwater.

The quarries from which the stone used for building St. Paul's Cathedral was obtained were situated at the northern extremity of the island, but have been long abandoned in consequence of the stone being somewhat harder and more difficult to work than that met with in other parts of the island. The principal beds of stone quarried in the Isle of Portland are called, in descending order, *roach* or *roche*, *rubbly bed*, and *whit* (*i.e.* white) or *best* bed. These beds vary much in thickness, but they may be stated to average five and six feet respectively; some reaching fifteen feet.

The roach affords large blocks of a hard and durable white stone, particularly adapted for foundations of buildings, docks, breakwaters, and other constructions where great strength is required; but, owing to the numerous cavities it contains (produced by the empty casts of shells), it will not receive a close, even face, and is therefore not so well adapted for many other purposes of a more ornamental description. The rubbly bed is not much worked; but the white or best bed, when accessible is always quarried, and affords a white oolitic freestone, which takes a smooth, even face, and works freely in all directions.

The following analysis by Professor Daniell, gives the chemical composition of this stone:—

Silica	1·20
Carbonate of lime	95·16
Carbonate of magnesia	1·20
Iron and alumina	0·50
Water and loss	1·94
Bitumen	trace
	100·00

The other principal localities where the Portland stone is quarried are the Isle of Purbeck in Dorsetshire, where it is called Purbeck-Portland; and the Vale of Wardour, where (as at Chilmark and other places) it affords a freestone of a superior description. From 56,000 to 60,000 tons of stone are raised annually in the Isle of Portland.—H. W. B.

POST. A North of England term for any bed of firm rock.

POTASH, or **POTASSA.** (*Potasse*, Fr.; *Kali*, Ger.) This substance was so named from being prepared for commercial purposes by evaporating in iron pots the lixivium of the ashes of wood-fuel. In the crude state it consists, therefore, of such constituents of burned vegetables as are very soluble in water, and fixed in the fire. The potash-salts of plants which originally contained vegetable acids will be converted into carbonates; the sulphates will become sulphites, sulphides, or even carbonates, according to the manner of incineration; the nitrates will be changed into pure carbonates, while the muriates or chlorides will remain unaltered. Should quicklime be added to the solution of the ashes, a corresponding portion of caustic potassa will be introduced into the product, with more or less lime, according to the care taken in decanting off the clear lye for evaporation.

In America, where timber is in many places an incumbrance upon the soil, it is felled, piled up in pyramids, and burned, solely with a view to the manufacture of potash. The ashes are put into wooden cisterns, having a plug at the bottom of one of the sides under a false bottom; a moderate quantity of water is then poured on the mass, and some quicklime is stirred in. After standing for a few hours, so as to take up the soluble matter, the clear liquor is drawn off, evaporated to dryness in iron pots, and finally fused at a red heat into compact masses, which are grey on the outside and pink-coloured within.

Pearlash is prepared by calcining potashes upon a reverberatory hearth, till the whole carbonaceous matter, and the greater part of the sulphur, be dissipated: then lixiviating the mass in a cistern having a false bottom covered with straw, evaporating the clear lye to dryness in flat iron pans, and stirring it towards the end into white lumpy granulations.

The best pink Canadian potashes, as they are imported in casks containing about 5 cwts., contain pretty uniformly 60 per cent. of absolute potassa; and the best pearlashes contain 50 per cent.; the alkali in the former being nearly in a caustic state; in the latter carbonated.

All kinds of vegetables do not yield the same proportion of potash. The more succulent the plant, the more does it afford; for it is only in the juices that the vegetable salts reside, which are converted by incineration into alkaline matter. Herbaceous weeds are more productive of potash than the graminiferous species, or shrubs, and these than trees; and for a like reason twigs and leaves are more productive than timber. But plants in all cases are richest in alkaline salts when they have arrived at maturity. The soil in which they grow also influences the quantity of saline matter.

The following Table exhibits the average product in potash of several plants, according to the researches of Vauquelin, Pertuis, Kirwan, and De Saussure:—

In 1000 parts	Potassa	In 1000 parts	Potassa	In 1000 parts	Potassa
Pine or fir	0·45	Boxwood	2·26	Thistles	5·00
Poplar	0·75	Willow	2·85	Flax-stems	5·00
Trefoil	0·75	Elm and maple	3·90	Small rushes	5·08
Beechwood	1·45	Wheat-straw	3·90	Vine-shoots	5·50
Oak	1·53	Bark of oak-twigs	4·20	Barley-straw	5·80

In 1000 parts	Potassa	In 1000 parts	Potassa	In 1000 parts.	Potassa
Dry beech-bark	6·00	Bastard chamomile (*Anthemis cotula*, L.)	19·6	Thistles in full growth	35·37
Fern	6·26	Sunflower-stalks	20·00	Dry straw of wheat before earing	47·0
Large rush	7·22	Common nettle	25·03	Wormwood	73·0
Stalk of maize	17·5	Vetch plant	27·50	Fumitory	79·0
Bean-stalks	20·0				

Stalks of tobacco, potatoes, chestnuts, chestnut-husks, broom, heath, furze, tansy, sorrel, vine-leaves, beet-leaves, orach, and many other plants, abound in potash salts. In Burgundy, the well-known *cendres gravitées* are made by incinerating the lees of wine pressed into cakes, and dried in the sun; the ashes contain fully 16 per cent. of potash. See Ashes of Plants.

The purification of pearlash is founded upon the fact of its being more soluble in water than the neutral salts which debase it. Upon any given quantity of that substance, in an iron pot, let one and a half times its weight of water be poured, and let a gentle heat be applied for a short time. When the whole has again cooled, the bottom will be encrusted with the salts, while a solution of nearly pure carbonate of potash will be found floating above, which may be drawn off clear by a syphon. The salts may be afterwards thrown upon a filter of gravel. If this lye be diluted with six times its bulk of water mixed with as much slaked lime as there was pearlash employed, and the mixture be boiled for an hour, the potash will become caustic, by giving up its carbonic acid to the lime. If the clear, settled lixivium be now syphoned off, and concentrated by boiling in a covered iron pan, till it assumes the appearance of oil, it will constitute the common 'caustic' of the surgeon, the *potassa fusa* of the shops. But to obtain potash chemically pure, recourse must be had to the bicarbonate, nitrate, or tartrate of potash, salts which, when carefully crystallised, are exempt from anything to render the potash derived from them impure. The bicarbonate having been gently ignited in a silver basin, is to be dissolved in six times its weight of water, and the solution is to be boiled for an hour, along with 1 lb. of slaked lime for every pound of the bicarbonate used. The whole must be left to settle without contact of air. The supernatant lye is to be drawn off by a syphon, and evaporated in an iron or silver vessel, provided with a small orifice in its close cover for the escape of the steam, till it assumes, as above, the appearance of oil, or till it be nearly red-hot. Let the fused potash be now poured out upon a bright plate of iron, cut into pieces as soon as it concretes, and put up immediately in a bottle furnished with a well-ground stopper. It is a hydrate of potash, being composed of 1 atom of potash 48, + 1 atom of water 9 = 57; or KO.HO (**KHO**).

A pure carbonate of potash may be also prepared by fusing pure nitre in an earthen crucible, and projecting charcoal into it by small bits at a time, till it ceases to cause deflagration. Or a mixture of 10 parts of nitre and 1 of charcoal may be deflagrated in small successive portions in a red-hot deep crucible. When a mixture of 2 parts of tartrate of potash, or crystals of tartar, and 1 of nitre is deflagrated, pure carbonate of potash remains mixed with charcoal, which by lixiviation, and the agency of quicklime will afford a pure hydrate. Crystals of tartar calcined alone yield also a pure carbonate.

In addition to the ashes of plants, other sources of potash are now utilized. The most important of these sources are the potash-minerals occurring in the upper part of the great salt-deposits of Stassfurt in Prussian Saxony and Kalucz in Galicia. These salts are *sylvine*, or chloride of potassium; *carnallite*, or chloride of potassium and magnesium; and *kainite*, a sulphate of potash and magnesia, with chloride of magnesium. See Abraum Salts.

Potash has also been extracted from certain felspars, from sea-water, from beet-root molasses, from the ash of sea-weeds, and from the suint of wool. But these sources are insignificant when compared with the great deposits of potash salts occurring naturally at Stassfurt, which have of late years been worked on a very extensive scale.

The Production of Potash Salts at Stassfurt.—A few details on these mines, which have produced so great a revolution in the manufacture of potash salts, will be useful. Stassfurt is situate about 20 kilos from Magdeburg, on the Anhalt frontier. The geological formation on which it lies is the Bunter Sandstone. The presence of a bed of rock-salt below this stratum was suspected in 1838. Borings were executed by order of the Prussian Government, and in 1851 the presence of a deposit of rock-salt, at least 330 meters in thickness, was ascertained. The formal working of the mines began in 1857. Before reaching the salt it was necessary to sink 260 meters through the sandstone, the gypsum, and the marl.

The saline deposit does not consist exclusively of common salt, and may be divided into four chief regions. The lowest bed is the largest, and consists entirely of rock-salt, traversed by slender veins of karstenite. It is about 240 meters in thickness.

We find next the region of *polyhalite*, still composed of rock-salt, but intersected by veins of 2 to 3 c.m. thick, formed of polyhalite, a mineral composed of the sulphates of lime, magnesia, and potash. This layer is about 64 meters in thickness, and is composed on an average of 91·2 per cent. chloride of sodium, 0·66 of karstenite, 6·63 of polyhalite, and 1·51 of hydrated chloride of magnesium.

To this stratum succeeds another of a different composition, and characterised by the presence of a saline mineral named *kieserite*. It consists of mono-hydrated sulphate of magnesia, in small microscopic needles. The layer contains 65 per cent. of chloride of sodium, 17 of kieserite, 13 of carnallite, 3 of chloride of magnesium, and 2 of karstenite. Its thickness is 56 meters. The upper region is formed of a group of salts chiefly magnesic and potassic, and formerly called *riddance salts* (*Abraumsalze*), because they were at first without industrial application, and were merely extracted to reach the rock-salt below. These salts are now the foundation of the trade of Stassfurt. The principal salt is *carnallite*, a chloride of potassium and magnesium. It has a red colour, due to the presence of oxide of iron in microscopic lamellæ. There are found also in this deposit *sylvine* and *Howellite*, a chloride of potassium containing often small quantities of sulphate of potash, and of sulphate and chloride of magnesium; *tachyhydrite*, a carnallite in which the chloride of potassium is replaced by chloride of calcium; and *boracite*, a combination of the borate and chloride of magnesium. Stassfurt, as we have stated, lies on the Prussian frontier, towards the borders of the Duchy of Anhalt. The Prussian workings, therefore, could not be extended to the south-west, where the geological conditions were most favourable. In 1855 the Government of Anhalt commenced operations within its own territory, with perfect success. The saline beds were reached at the depth of 145 meters, and soon a new salt was discovered in great quantity, giving a new impulse to the trade of the district. This is *kainite*, a compound of sulphate of magnesia and chloride of magnesium. Its discovery enabled the inhabitants to enter upon the manufacture of pure sulphate of potash, which is largely exported to England and the United States. Their applications are numerous. The chloride of potassium is used in the manufacture of saltpetre and carbonate of potash; the sulphate of potash is in great demand in the glass and alum works. Stassfurt exports also sulphate of magnesia and chloride of magnesium, which are extensively used in England for the discreditable purpose of adding to the weight of textile goods, and rendering them hygroscopic; bromine to an extent almost sufficient for the consumption of Europe, and boracic acid. Lastly, the impure salts obtained as waste in the various refining processes, consisting principally of salts of soda, magnesia, and potash, are skilfully combined, and sold as mineral manures, more or less rich in potash and magnesia. The demand for these manures has greatly increased of late years, especially in England and Germany. In 1869 the Prussian mine alone yielded 109,075,000 kilos of salts of potash, and 56,332,000 kilos of rock-salt, representing a total value of 916,960 francs. It is interesting to note that whereas the application of potassic salts in agriculture, some fifteen or twenty years ago, was found to produce little or no benefit, they are shown by more recent experiments to be highly valuable. Liebig has shown that the use of manures which contain only *some* of the ash-constituents of the crops merely enables the soil to be more rapidly exhausted of the other necessary constituents. See CARNALLITE; KAINITE; KIESERITE; SYLVINE.

Caustic potash, after being fused in a silver crucible at a red heat, retains 1 equivalent of water. Hence its composition in 100 parts is, potassium 70, oxygen 14, water 16. *Anhydrous potash*, or the oxide free from water, can be obtained only by the oxidation of potassium in air. It is composed of 83⅓ of metal and 16⅔ of oxygen.

Caustic potash may be crystallised; but in general it occurs as a white brittle substance of spec. grav. 1·708, which melts at a red heat, evaporates at a white heat, deliquesces into a liquid in the air, and attracts carbonic acid; is soluble in water and alcohol, forms soft soaps with fat oils, and soapy-looking compounds with resins and wax; dissolves sulphur, some metallic sulphurets, as those of antimony, arsenic, &c., as also silica, alumina, and certain other bases; and decomposes animal textures, as hair, wool, silk, horn, skin, &c. It should never be touched with the tongue or the fingers.

The only certain way of determining the quantity of free potash in any solid or liquid is from the quantity of a dilute acid of known strength which it can saturate.

The hydrate of potash or its lye often contains a notable quantity of carbonate, the presence of which may be detected by lime-water, and its amount be ascertained by the loss of weight which it suffers, when a weighed portion of the lye is poured into a weighed portion of dilute sulphuric acid poised in the scale of a balance.

The following Table exhibits the quantity of potash in 100 parts of *caustic lye*, at the respective densities:—

Sp. gr.	Pot. in 100	Sp. gr.	Pot. in 100	Sp. gr.	Pot. in 100	Sp. gr.	Pot. in 100	Sp. gr.	Pot. in 100
1·58	53·06	1·46	42·31	1·34	32·14	1·22	23·14	1·10	11·28
1·56	51·58	1·44	40·17	1·32	30·74	1·20	21·25	1·08	9·20
1·54	50·09	1·42	37·97	1·30	29·34	1·18	19·34	1·06	7·02
1·52	48·46	1·40	35·99	1·28	27·86	1·16	17·40	1·04	4·77
1·50	46·45	1·33	34·74	1·26	26·34	1·14	15·38	1·02	2·44
1·48	44·40	1·36	33·46	1·24	24·77	1·12	13·30	1·00	0·00

POTASH, BICARBONATE OF, is prepared by passing carbonic acid through a solution of the carbonate of potash. See BICARBONATES.

POTASH, BICHROMATE OF. See CHROMATES OF POTASH.

POTASH, BINOXALATE OF. *Salt of wood sorrel; Salt of sorrel; Sal acetosella.* (*Sel d'oseille*, Fr.)

The *Oxalis acetosella* is an odourless plant, but in taste it is agreeably acidulous. In some parts of Germany the binoxalate of potash is obtained in large quantities from this plant by evaporating the expressed juice. Five hundred parts of the plant yield four parts of the crystallised salt; its composition is, oxalic acid 2 parts, potash 1 part, water 2 parts.

It is sold under the name of *salt of lemons*, sometimes in a pure state, but more frequently mixed with *cream of tartar*, and is used for the removal of iron stains from linen.

POTASH, BITARTRATE OF. *Cream of tartar.* This salt is a constituent of many vegetable juices, especially of the juice of the grape. All the salt of commerce is obtained during the vinous fermentation; it deposits during the process of the formation of alcohol, and accordingly as it is obtained from white or red wine it is known by the name of *white or red argol*. The acid tartar is thus prepared in the wine-making districts of France.

Argol, which occurs in crystalline cakes, and is composed of the bitartrate of potash, tartrate of lime, and colouring-matter, is boiled in water; and the solution allowed to cool, by which a deposit of crystals is obtained. These are washed with cold water, and then dissolved in boiling water, in which are diffused clay and charcoal, which as they fall down receive the colouring-matter. The clear liquor is allowed to cool slowly, and crystals form.

This salt consists of potash 25·00, tartaric acid 70·21, water 4·79.

If cream of tartar is heated it is decomposed, swells up, evolves gaseous products, and is converted into *Black Flux*. See ASSAYING.

POTASH, CARBONATE OF. *Salt of tartar; Potashes; Pearlashes.* If land plants are burnt their ashes will be found to contain a considerable quantity of the carbonate of potash.

Carbonate of potash is composed of 48 parts of base and 22 of acid; or, in 100 parts, of 68·09 of potash and 31·91 of carbonic acid: that is, $KO.CO^2$ ($\mathbf{K^2CO^3}$).

Carbonate of potash, as it exists associated with carbon in calcined tartar, passes very readily into the *bicarbonate*, on being moistened with water, and having a current of carbonic acid gas passed through it. The absorption takes place so rapidly, that the mass becomes hot, and therefore ought to be surrounded with cold water. See POTASH.

POTASH, CAUSTIC. See POTASH.

POTASH, CHLORATE OF. See CHLORATE OF POTASH.

POTASH, CITRATE OF. This salt is formed by neutralising citric acid with carbonate of potash. Under the names of *lemon and kali, effervescing lemonade*, and the like, mixtures of dry citric acid in powder and dry carbonate of potash, with very dry sugar, are sold. These form very agreeable and healthful beverages.

POTASH, HYDRATE OF, or **CAUSTIC POTASH.** (*Potasse*, Fr.; *Kali*, Ger.) It may be obtained thus:—Mix a solution of 1 part of the dry carbonate of potash with 1 part of freshly-prepared dry hydrate of lime, and allow it to stand in a closed vessel for 24 hours at a temperature of 68° to 78° Fahr., frequently shaking it. The potash salt should be dissolved in 12 to 15 parts of water; the carbonate of lime separates in a granulated state, and the clear caustic lye may be decanted. A weaker lye may be obtained from the residue by fresh treatment with water. See POTASH.

POTASH, NITRATE OF. $KO.NO^5$ ($\mathbf{KNO^3}$.) Syns. *Nitre, Saltpetre, Prismatic nitre.* (*Nitrate de potasse*, Fr.; *Salpetersäures Kali*, Ger.) For the mode of purification, see GUNPOWDER. This well-known and useful salt is found native in various parts of the world, more especially in tropical climates. The formation of nitre in the earth appears to be much facilitated by warmth.

Preparation.—1. By lixiviation of earth impregnated with the salt. The earth is heated with water in tanks or tubs with false bottoms, and after sufficient digestion the solution is run off and evaporated to crystallisation. The nitre procured by the first operation is exceedingly impure, and contains large quantities of chloride of potassium, and some sulphate of potash. By repeated crystallisations the salt may be obtained pure. If the crude product of the lixiviation contains, as is often the case, the nitrates of lime or magnesia, they may be got rid of by the addition of carbonate of potash; the earths are precipitated as carbonates, and may be filtered off, while an equivalent quantity of nitrate of potash is formed, and remains in solution, thus:—

$$\mathrm{CaO.NO^5 + KO.CO^2 = CaO.CO^2 + KO.NO^5}.\ [\mathbf{Ca(NO^3)^2 + K^2CO^3 = CaCO^3 + 2KNO^3}.]$$

2. The second mode of preparing nitre which we shall consider, is from nitrate of soda and chloride of potassium. On dissolving equivalent quantities of these two salts in water, and salting down, double decomposition takes place. The chloride of sodium may be removed from the hot concentrated fluid by means of shovels, while the nitrate of potash, being much more soluble in hot than in cold water, remains in solution, but crystallises out on cooling. The decomposition takes place in accordance with the annexed equation:—

$$\mathrm{NaO.NO^5 + KCl = NaCl + KO.NO^5}.\quad (\mathbf{NaNO^3 + KCl = NaCl + KNO^3}.)$$

The above reaction is one of great interest and importance, inasmuch as it enables us to convert Peruvian or 'cubic nitre,' as nitrate of soda is sometimes called, into the much more valuable salt, nitrate of potash. During the last war with Russia it was found that large quantities of chloride of potassium were exported, and found their way into that country. For some time no notice was taken, because the salt appeared too harmless to be declared contraband of war. Eventually it was found that it was entirely used in Russia for the purpose of affording nitrate of potash, by the process described. It need scarcely be said that the gunpowder made through the medium of our own chloride of potassium was employed against our troops in the Crimea.

3. Nitre may of course be prepared by neutralising nitric acid by means of carbonate of potash, or the caustic alkali. The process is evidently too expensive to be employed, except for the purpose of experimental illustration, or under other special circumstances.

The formation of nitre in the earth of hot climates is probably in most cases due to the decomposition of nitrogenised organic matters. The subject of nitrification is one upon which some controversy has taken place. It is supposed by some chemists that the chief source of the nitric acid is the ammonia produced during the decay of nitrogenous matters. The presence of bases appears to have a remarkable tendency to increase the production of the acid. It has been asserted that the ammonia which is produced suffers partial oxidation, the acid formed uniting with the undecomposed ammonia to form the nitrate of that alkali. On the other hand, it has been argued that the ammonia does not suffer oxidation, but that the nitrogen produced during the decay of organic matter combines, at the instant of its liberation with oxygen, to form nitric acid, which unites with the bases present. Nitrate of ammonia, no matter how formed, suffers double decomposition in presence of the carbonates of the alkaline earths, the result being the production of the nitrates of lime and magnesia. It is owing to the presence of the two latter salts in the crude liquor obtained by lixiviating nitrified earth, that the addition of carbonate of potash is so important, and causes so great an increase in the produce of nitre. It has been insisted by some observers that the presence of nitrogenous organic matters is not essential to the production of nitre. In support of this, it has been shown that large quantities of nitrates are often found where little or no organic matters are present. This has been explained by assuming that porous bodies have the power of absorbing water, oxygen, and nitrogen, and producing nitric acid from them. But it is evident that other forces exist capable of inducing the oxidation of atmospheric nitrogen. It has been experimentally demonstrated that nitric acid is produced during the discharge of atmospheric electricity. It is also probable that ozone plays an important part in the phenomena of nitrification. Perhaps most of the chemists who have investigated the subject, have been too anxious to assign the formation of nitre to one particular cause, whereas, the phenomena which have been noticed by different observers are in favour of the idea that several agencies are at work during the production of nitrates in the earth and in artificial nitre-beds.

During the time that France was fighting single-handed against the rest of Europe, great difficulty was found in obtaining sufficient nitre for the production of the vast amount of gunpowder necessary to enable her artillery to be effectively supplied with ammunition. This led the French chemists to establish artificial nitre-beds in various parts of the country. The success of the process may be judged of from the fact that they yielded 2,000 tons annually.

Nitre crystallises in colourless six-sided prisms. The crystals are anhydrous; large specimens when broken, however, generally show the presence of a little moisture mechanically adhering to the interstices. If wanted in fine powder, it must therefore be first coarsely bruised, and then dried, after which it may be finely pulverised and sifted.

By the careful application of heat, nitrate of potash may be melted without undergoing any decomposition or loss of weight. But if the heat be raised to redness, it begins to decompose, the degree to which the change takes place depending on the amount of heat and the time of exposure. By carefully heating, for some time, a large quantity of nitrite of potash is formed, oxygen gas being evolved. If the heat be raised, or the exposure to a high temperature be continued, a large quantity of nitrogen accompanies the oxygen, and the nitre becomes more and more changed, until finally, a mixture of potash with peroxide of potassium is attained. If copper filings, clipping, or shreds be mixed with the nitre, the decomposition proceeds much more readily, and Wöhler has proposed to prepare pure potash by this means. At high temperatures nitre is a potent agent of oxidation, so much so, that the diamond itself is attacked and converted into carbonic acid, which unites with the potash. Crystallised boron, which is said to equal if not exceed the diamond in hardness, is not attacked by fused nitre. The oxidising power of nitre is made use of in the arts in order to obtain bichromate of potash from chrome iron ore.

Nitrate of potash is sometimes used as a source of nitric acid, but nitrate of soda is in every way more economical. This will be evident when it is considered that it takes 101 parts of nitrate of potash to yield one equivalent of dry nitric acid (54 parts), whereas 85 parts of nitrate of soda yield the same amount of acid. See NITRIC ACID.

Nitrate of potash is employed in blow-pipe experiments, in order to assist in the production of the green reaction characteristic of the presence of manganese. It often happens where the quantity of manganese is exceedingly small, as in rose quartz, that the green coloration with soda on platinum foil cannot be obtained; if, however, a little nitre be added, and the testing be repeated, the reaction generally appears without any trouble.

Nitrate of potash is greatly employed in the preparation of pyrotechnic mixtures. It ought always to be well dried and reduced to fine powder before being used.

Nitre is not unfrequently employed by the chemist for determining the percentage of sulphur in coal. For this purpose the coal, reduced to fine powder, is mixed with nitre and carbonate of soda, and projected by small portions into a silver crucible, maintained at a red heat. A platinum crucible must not be employed, as it is attacked by nitre in a state of fusion. The sulphur in the coal is converted, by the oxidising agency of the nitre, into sulphuric acid; the latter can then be converted into sulphate of baryta, and the percentage of sulphur ascertained from its weight.

Estimation of the Value of Nitre.—A great number of processes have been devised for the determination of the percentage of pure nitrate of potash in samples of the crude salt. All these processes are more or less incorrect, and a really accurate mode of determining the value of nitre has long been felt as a want by chemists. This want has been supplied by Messrs. Abel and Bloxam of the Woolwich Arsenal, who have devoted much labour and skill to the subject. Before detailing the successful process of the latter chemists, we will take a brief glance at the other methods commonly used for the purpose. The French process depends upon the principle that a solution, when saturated with one salt, is still capable of dissolving a considerable quantity of saline matter differing in its nature from the first. If, therefore, a saturated solution of nitre be poured upon pure nitre, no more is dissolved if the temperature remains the same as it was when the original solution was prepared. But if, on the other hand, the saturated solution of nitre be digested with an impure sample containing the chlorides of sodium, potassium, &c., the latter salts will be dissolved, and the pure nitre remaining can, after proper draining, &c., be dried and weighed. The loss of weight obviously represents the impurities removed. This process is subject to so many sources of error that the practical details need not be entered into.

Another mode of valuing nitre consists in fusing the salt, and, after cooling, breaking the cake: the fineness or coarseness and general characters of the fracture are the means whereby the greater or less value of the salt are ascertained. This process, which is known as the Swedish or Swartz's method, is far too dependent on the individual experience and dexterity of the operator to be of any value in the hands of the chemist whose attention is only now and then directed to the valuation of saltpetre. Moreover, although those who are in the habit of using it possess some confidence in its correctness, it is quite evident that it is impossible for such an operation to yield results of analytical accuracy.

The Austrian method has also been used by some, but it is quite inadmissible as a general working process. It consists in ascertaining the temperature at which the solution crystallises.

Gossart's method consists in determining the value of the nitre by measuring its power of oxidation. The latter is accomplished by finding the quantity of protoxide of iron which it can convert into peroxide. If to an acid solution of protosulphate of iron nitric acid or a nitrate be added, the proto is converted into a persalt at the expense of a portion of the oxygen of the nitric acid.

M. Pelouze endeavoured to improve the above process by using such an excess of the protosalt of iron that the nitre added should be able to convert only a portion of it into a persalt. The remaining protoxide was then converted into persalt by means of a solution of permanganate of potash of known strength. The data so obtained enabled the value of the nitre to be estimated. But even this process is liable to variations, so much so, indeed, that Messrs. Abel and Bloxam obtained in eleven experiments made with pure nitre as many different results.

The next process which we shall notice is that which the chemists generally have settled upon as yielding the best results. It is that of M. Gay-Lussac. It depends on the fact that if nitrate of potash be heated with charcoal, or, in fact, any carbonaceous matters in excess, the nitrate is converted into carbonate of potash, the amount of which may be accurately estimated by means of a standard solution of sulphuric acid. The chlorides which may be present are unacted upon by the charcoal, and do not, therefore, influence the result; but if sulphates be present, they are reduced by the carbon to sulphides, which, in consequence of being decomposed by the sulphuric acid, may cause serious errors. Fortunately the amount of sulphuric acid present in nitre is seldom sufficient to cause any great error. Any nitrate of soda present would come out in the final result as nitrate of potash, and thus become another source of error; in practice this is seldom likely to occur. The original process consists in weighing out 20 grammes (308·69 grains) of crude saltpetre, and mixing it with 5 grammes (77·17 grains) of charcoal, and 80 grammes (1234·7 grains) of chloride of sodium. The mixture is thrown little by little into a red-hot crucible, and, when the decomposition is over, allowed to cool. The residual mass is dissolved in water, filtered, and water passed through the filter until it amounts to 200 cubic centimeters (12·2 cubic inches). The amount of alkali is then ascertained with a burette and standard sulphuric acid. (See ALKALIMETER.) Messrs. Abel and Bloxham have minutely and laboriously studied this operation, and detected its sources of difficulty and error. Their researches have led them to employ the following modification:—

Twenty grains of the sample are to be well mixed in a platinum crucible with 30 grains of finely-powdered resin and 80 grains of pure dry common salt. The heat of a wire-gauze flame is then applied, until no more vapour is given off. The crucible is then allowed to cool down a little, and 25 grains of chlorate of potash are added. A gentle heat is then applied until most of the chlorate is decomposed; the heat is then raised to bright redness for two or three minutes. The mass should be fluid, and free from floating charcoal. The mass, when cool, is removed to a funnel, and the crucible, &c., washed with boiling water. The mass is then dissolved in hot water, and the entire solution, coloured by litmus, is neutralised with the standard acid. In the annexed table 20 grains of pure nitre were taken for each experiment:—

Exp.	Nitre found	Nitre per cent.
1	20·00	100·00
2	20·00	100·00
3	19·97	99·85
4	19·97	99·85
5	20·08	100·40
6	20·08	100·40
7	20·08	100·40

These chemists, not yet satisfied, made 53 more experiments by this method. The mean result with pure nitre was 99·7 per cent. The mean of 25 of the above experiments was 98·7 per cent. The mean of the remainder was 100·7.

Subsequent experiments showed that greater accuracy might be obtained by substituting, for the resin, pure ignited finely-divided graphite, prepared by Professor Brodie's patented process. To perform the process, 20 grains of the nitre are to be mixed with 5 grains of ignited graphite and 80 grains of salt. The general process is conducted in the manner described in the operation with resin. The results are very exact, and apparently quite sufficient for all practical purposes.

POTASH, NITRITE OF. $KO.NO^3$ (**KNO^2**). When ordinary saltpetre, or nitrate of potash, is heated with sulphuric acid, in the cold, no special reaction becomes evident, as far as any evolution of gas is concerned; but if, previous to the addition of the acid, the nitre be strongly fused, it will be found, as soon as the admixture takes place, that red fumes are evolved. This arises from the fact, that nitrate of potash, when subjected to strong ignition, is decomposed with evolution of oxygen, the nitrate becoming gradually converted into the nitrite of potash, thus:—

$$KO.NO^5 = KO\ NO^3 + 2O. \quad (\mathbf{2KNO^3 = 2KNO^2 + O^2}).$$

This reaction acquires great interest from the circumstance, that to its correct explanation was owing the commencement of the fame of the illustrious Swedish chemist Scheele. A pharmaceutist, at Upsala, having heated some saltpetre to redness in a crucible, happened, when it became cold, to pour vinegar over it, when, to his surprise, red fumes were evolved. Gahn was applied to for an explanation; but, unable to comprehend the matter, he applied to Bergmann; but even he was as much in the dark as Gahn. The explanation which these eminent chemists were unable to give was supplied by the pharmaceutist's apprentice, the young Scheele. Bergmann, when informed by Gahn of Scheele's explanation, felt a strong desire to make his acquaintance, and ultimately they were introduced to each other.

Nitrite of potash has acquired some importance of late years, owing to the valuable properties, as a decomposing agent, which have been found by chemists to reside in nitrous acid.

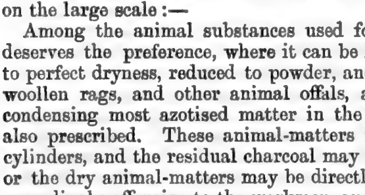
Preparation.—Nitrate of potash is to be fused at a red heat for a considerable time. When cold, the contents of the crucible are to be dissolved out with boiling water, and the nitrate of potash remaining is to be removed as far as possible by crystallisation. The nitrite of potash may be obtained from the mother-liquor by evaporation and subsequent crystallisation. It is a neutral salt which deliquesces on exposure to the air. If a piece of strongly-fused nitre be put, when cold, into a solution of sulphate of copper, a very beautiful apple-green colour is produced, of a tint which is seldom observed, except in solutions containing the nitrite of that metal.

POTASH, PRUSSIATE OF. *Ferrocyanide of potassium or Yellow prussiate of potash.* $K^2FeCy^3 + 3HO$ ($\mathbf{K^4FeCy^6 + 3H^2O}$).

This salt occurs in a state of great purity in commerce, and is thus manufactured on the large scale:—

Among the animal substances used for the preparation of this lixivium, blood deserves the preference, where it can be had cheap enough. It must be evaporated to perfect dryness, reduced to powder, and sifted. Hoofs, parings of horns, hides, old woollen rags, and other animal offals, are, however, generally had recourse to, as condensing most azotised matter in the smallest bulk. Dried funguses have been also prescribed. These animal-matters may either be first carbonised in cast-iron cylinders, and the residual charcoal may then be taken for making the ferroprussiate; or the dry animal-matters may be directly employed. The latter process is apt to be exceedingly offensive to the workmen and neighbourhood, from the nauseous vapours that are exhaled in it. Eight pounds of horn (hoofs), or ten pounds of dry blood, afford upon an average one pound of charcoal. This must be mixed well with good pearlash, (freed previously from most of the sulphate of potash, with which it is always contaminated,) either in the dry way, or by soaking the bruised charcoal with a strong solution of the alkali: the proportion being one part of carbonate of potash to from 1½ to 2 parts of charcoal, or to about 8 parts of hard animal-matter.

1636



The pot for calcining the mixture of animal and alkaline matter is egg-shaped, as represented at *a*, *fig.* 1636, and is considerably narrowed at the neck *e*, to facilitate the closing of the mouth with a lid *i*. It is made of cast iron, about two inches thick in the belly and bottom; this strength being requisite because the chemical action of the materials wears the metals away fast. It should be built into the furnace in a direction sloping downwards, (more than is shown in the figure,) and have a strong knob *b*, projecting from its bottom to support it upon the back wall, while its shoulder is embraced at the arms *o*, *c*, by the brickwork in front. The interior of the furnace is so formed as to leave but a space of a few inches round the pot, in order to make the flame play closely over its whole surface. The fire-door *f*, and the draught-hole, *x*, of the ash-pit, are placed in the posterior part of the furnace, in order that the workmen may not be incommoded by the heat. The smoke-vent *o*, issues through the arched top, *h*, of the furnace, towards the front, and is thence led backwards by a flue to the main chimney of the factory. *d* is an iron or stone shelf, inserted before the mouth of the pot, to prevent loss in shovelling out the semi-liquid paste. The pot may be half filled with the materials.

The calcining process is different, according as the animal substances are fresh or carbonised. In the first case, the pot must remain open, to allow of diligent stirring of its contents, with a slightly bent flat iron bar or scoop, and of introducing more of the mixture as the intumescence subsides, during a period of five or six hours, till the nauseous vapours cease to rise, till the flame becomes smaller and brighter. and till a smell of ammonia be perceived. At this time the heat should be increased, the mouth of the pot should be shut, and opened only once every half-hour, for the purpose of working the mass with the iron paddle. When on opening the mouth of the pot, and stirring the pasty mixture, no more flame rises, the process is finished.

If the animal ingredients are employed in a carbonised state, the pot must be shut as soon as its contents are brought to ignition by a briskly-urged fire, and opened for a few seconds only every quarter of an hour, during the action of stirring. At first, a body of flame bursts forth every time that the lid is removed; but by degrees this ceases, and the mixture soon agglomerates, and then softens into a paste. Though the fire be steadily kept up, the flame becomes less and less each time that the pot is opened; and when it ceases, the process is at an end. The operation, with a mass of 50 pounds of charcoal and 50 pounds of purified pearlash, lasts about 12 hours the first time that the furnace is kindled; but when the pot has been previously brought to a state of ignition, it takes only 7 or 8 hours. In a well-appointed factory the fire should be invariably maintained at the proper pitch, and the pots should be worked with relays of operatives.

The molten mass is now to be scooped out with an appropriate iron shovel, having a long shank, and caused to cool in small portions, as quickly as possible; but not by throwing it into water, as has sometimes been prescribed, for in this way a good deal of the cyanogen is converted into ammonia. If it be heaped up and kept hot in contact with air, some of the ferrocyanide is also decomposed, with diminution of the product. The crude mass is to be then put into a pan with cold water, dissolved by the application of a moderate heat, and filtered through cloths. The charcoal which remains upon the filter possesses the properties of decolouring syrups, vinegars, &c., and of destroying smells in a pre-eminent degree. It may also serve, when mixed with fresh animal-charcoal, for another calcining operation.

As the iron requisite for the formation of the ferrocyanide is in general derived from the sides of the pot, this is apt to wear out into holes, especially at its under side, where the heat is greatest. In this event it may be taken out of the furnace, patched up with iron-rust cement, and reinserted with the sound side undermost. The erosion of the pot may be obviated in some measure by mixing iron borings or cinder with the other materials, to the amount of one or two hundredths of the potash.

The above lixivium is not a solution of pure ferroprussiate; it contains not a little cyanide of potassium, which in the course of the process had not absorbed the proper dose of iron to form a ferrocyanide; it contains also more or less carbonate of potash, with phosphate, sulphate, hydrogenated sulphuret, muriate, and sulpho-cyanide of the same base, as well as phosphate of lime; substances derived partly from the impure potash, and partly from the incinerated animal-matters. Formerly that very complex impure solution was employed directly for the precipitation of prussian blue; but now, in all well-regulated works, it is converted by evaporation and cooling into crystallised ferroprussiate of potash. The mother-water is again evaporated and crystallised, whereby a somewhat inferior ferroprussiate is obtained. Before evaporating the lye, however, it is advisable to add as much solution of green sulphate of iron to it as will re-dissolve the white precipitate of cyanide of iron which first falls, and thereby convert the cyanide of potassium, which is present in the liquor, into ferrocyanide of potassium. The commercial prussiate of potash may be rendered chemically pure by making its crystals effloresce in a stove, fusing them with a gentle heat in a glass retort, dissolving the mass in water, neutralising any carbonate and cyanide of potassium that may be present, with acetic acid, then precipitating the ferroprussiate of potash by the addition of a sufficient quantity of alcohol, and finally crystallising the precipitated salt twice over in water. The sulphate of potash may be decomposed by acetate of baryta, and the resulting acetate of potash removed by alcohol.

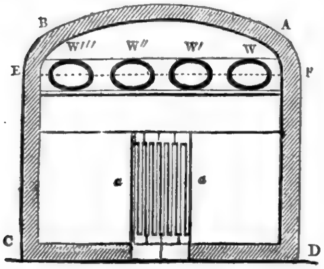
Berry's Patent Process.—Reduce charcoal into bits of the size of a walnut; soak them with a solution of carbonate of potash in urine, and then pour over them a solution of nitrate or acetate of iron; dry the whole by a moderate heat, and introduce them into the cast-iron tubes, presently to be described. The following proportions of constituents have been found to answer:—Ordinary potash, 30 parts; nitre, 10; acetate of iron, 15; charcoal or coke, 45 to 55; dried blood, 50. The materials, mixed and dried, are put into retorts similar to those for coal-gas. The animal-matter, however (the blood), is placed in separate compartments of pipes connected with the above retorts. The pipes containing the animal-matter should be brought to a red heat before any fire is placed under the retorts.

In *fig.* 1637, A B C D, is a horizontal section of a furnace constructed to receive four elliptical iron pipes. The furnace is arched in the part A B, in order to reverberate the heat, and drive it back on the pipes W, W′, W″, W‴. These pipes are placed on the plane E F, of the ellipsoid. *a a*, represents the grating or bars of the furnace to be heated with coal or coke; I I (*fig.* 1638), is the pot or retort.

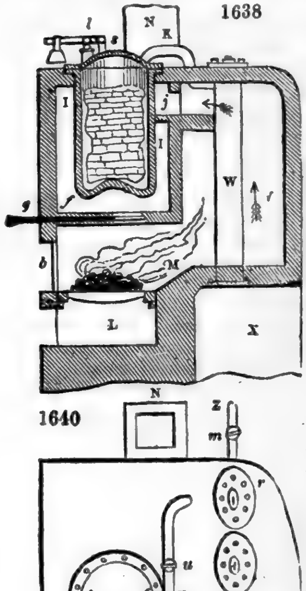
This pot or retort is placed in a separate compartment, as seen in *fig.* 1638, which is a vertical section, taken through *fig.* 1640 at the line G, H. K is a connecting tube from the retort and the elliptical pipes W.

In the section, *fig.* 1639, the shape of the tube K will be better seen; also its cocks *u*, and likewise its connection with the pipes W. *l*, (*fig.* 1638) is a safety-valve; *s*, the cover of the pot or retort; L, is the ash-pit; and *b*, the door of the furnace; X, is an open space, roofed over, or a kind of shed, close to the furnace, and under it the pipes are emptied; M, an inclined plane behind the fire-bars.

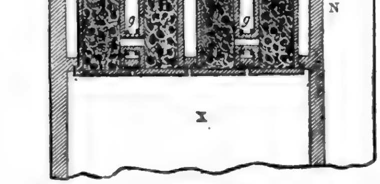
1637



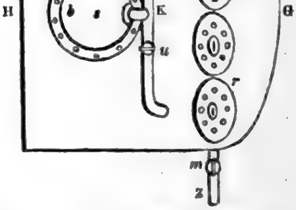
1638



1639



1640



The arrows indicate the direction of the current of heat. This current traverses the intervals left between the pipes, and ascends behind them, passing through the aperture *j*, in the brickwork, which is provided with a valve or damper, for closing it, as required. The heat passes through this aperture, and strikes against the sides of the pot when the valve is open. Another valve, *f*, *g*, must also be open to expose the pot or retort to the direct action of the fire. The smoke escapes by a lateral passage into a chimney, N.

It must be remarked that there is a direct communication between the chimney and that compartment of the furnace which contains the pipes, so that the heat, reflected from the part v, strikes on the pot or retort only when the pipes w, w, w″, w‴, are sufficiently heated.

In *fig.* 1639 are represented the junction-tubes, which connect the four pipes with their gas-burners, z, z, and the cocks *m m′*. *r, r, fig.* 1640, are covers, closing the pipes, and having holes formed in them; these holes are shut by the stoppers *e*.

Whether the pipes are placed in the vertical or horizontal position, it is always proper to be able to change the direction of the current of gas; this is easily done by closing, during one hour (if the operation is to last two hours), the cocks *u, m′* (*fig.* 1639), and opening those, *u′, m*; then the gas passes through *u′*, into the branch K, and entering w‴, passes through v into w′, through *g* into w′, and through 2nd *g* into w, and finally escapes by the burner z. During the following or other hour, the cocks *u′, m*, must be closed; the cocks *u, m′*, being opened, the current then goes from *u*, into K, w, w′, w″, w‴, and escapes by the burner z′, where it may be ignited.

The changing of the direction of the current dispenses, to a certain degree, with the labour required for stirring with a spatula the matters contained in the pipes; nevertheless, it is necessary, from time to time, to pass an iron rod or poker amongst the substances contained in the pipes. It is for this purpose that apertures are formed, so as to be easily opened and closed.

The patentee remarks, that although this operation is only described with reference to potash, for obtaining prussiate of potash, it is evident that the same process is applicable to soda; and when the above-mentioned ingredients are employed, soda being substituted for potash, the result will be prussiate of soda.

The process employed in the manufacture of ferrocyanide of potassium, by Hoffmayr and Prükner, is as follows:—The potash must be free from sulphate, for each atom of sulphur destroys an atom of the cyanide of potassium. A very strong heat is advantageous. The addition of from 1 to 3 per cent. of saltpetre is useful, when the mass is too long in fusing. A reverberatory furnace is recommended; but the flame must not beat too much upon the materials for fear of oxidising them. When the smoky red flame ceases, it is useful to throw in from time to time small portions of uncarbonised animal-matter, particularly where the flame first beats upon the mass, whereby the resulting gases prevent oxidation by the air. The animal-matters should not be too much carbonised, but left somewhat brown-coloured, provided they be readily pulverised. Of uncarbonised animal-matters, the proportions may be 100 parts dried blood, to from 28 to 30 of potash (carbonate), and from 2 to 4 of hammerslag (smithy scales), or iron filings. 2nd. 100 parts of horns or hoofs; from 33 to 35 potash; 2 to 4 iron. 3rd. 100 leather; 45 to 48 potash; and 2 to 4 iron. From blood, 8 to 9 per cent. of the prussiate are obtained; from horns, 9 to 10; and from leather, 5 to 6. The potash should be mixed in coarse particles, like peas, with the carbonised animal-matter, which may be best done in a revolving pot, containing cannon-balls. Of the animal-charcoal and potash equal parts may be taken, except with that from leather, which requires a few more parts of potash per cent. On the average, blood and horn-charcoal should afford never less than 20 per cent. of prussiate, nor the leather than 6; but by good treatment they may be made to yield, the first 25, and the last from 10 to 11.

POTASH, RED PRUSSIATE OF, or *Ferricyanide of potassium*, is prepared by passing chlorine gas through a solution of the ferrocyanide of potassium until it ceases to give a precipitate of Prussian blue, with a persalt of iron, and no longer. Its formula is $K^3Fe^2Cy^6$ ($\mathbf{K^3FeCy^6}$).

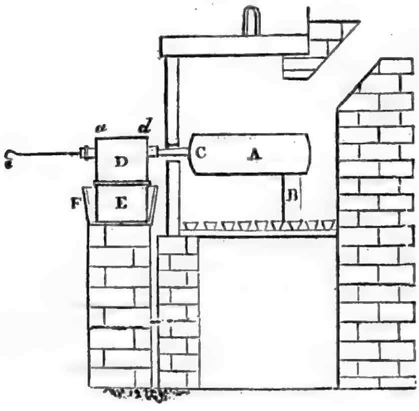
POTASSIUM (Eng. and Fr.; *Kalium*, Ger.) *Symb.* K; *At. wt.* 39. This is a metal deeply interesting, not only from its own properties, but from its having been the first link in the chain of discovery which conducted Sir H. Davy through many of the formerly mysterious and untrodden labyrinths of chemistry. It is the metallic base of potash.

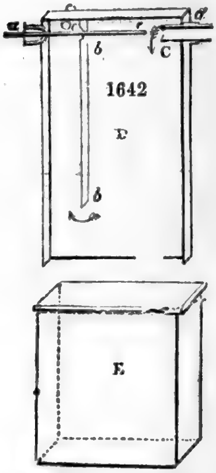
The easiest mode of obtaining this elementary substance is that contrived by Brünner. Into the orifice of one of the iron bottles, as A, *fig.* 1641, in which mercury is imported, adapt, by screwing, a piece of gun-barrel tube, 9 inches long; having brazed into its side, about three inches from its outer end, a similar piece of iron tube. Fill this retort two-thirds with a mixture of ten parts of cream of tartar, previously calcined in a covered crucible, and 1 of charcoal, both in powder; and lay it horizontally in an air furnace, so that while the screw orifice is at the inside wall, the extremity of the straight or nozzle-tube may project a few inches beyond the brickwork, and the tube brazed into it at right angles may descend pretty close to the outside wall, so as to dip its lower end a quarter of an inch beneath the surface of some rectified naphtha contained in a copper bottle surrounded by ice-cold water. By bringing the condenser vessel so near the furnace, the tubes along which the potassium-vapour requires to pass run less risk of getting obstructed. The horizontal straight end of the nozzle-tube should be shut by screwing a stopcock air-tight into it. By opening the cock momentarily, and thrusting in a hot wire, this tube may be readily kept free, without permitting any considerable waste of potassium. The heat should be slowly applied at first, but eventually urged to whiteness, and continued as long as potassuretted hydrogen continues to be disengaged. The retort and the part of the nozzle-tube exposed to the fire should be covered with a good refractory lute, as described under the article PHOSPHORUS. The joints must be perfectly air-tight; and the vessel freed from every trace of mercury, by ignition, before it is charged with the tartar-ash.

Tartar skilfully treated in this way will afford 3 per cent. of potassium; and when it is observed to send forth green fumes, it has commenced the production of the metal. Instead of the construction above described, the following form of apparatus may be employed:—

A, *fig.* 1641, represents the iron bottle, charged with the incinerated tartar; and B is a fire-brick support. A piece of fire-tile should also be placed between the bottom of the bottle and the back wall of the furnace, to keep the apparatus steady during the operation. Whenever the moisture is expelled, and the mass faintly ignited, the tube C should be screwed into the mouth of the bottle, through a small hole left for this purpose in the side of the furnace. That tube should be no longer, and the front wall of the furnace no thicker, than what is absolutely necessary. As soon as the reduction is indicated by the emission of green vapours, the receiver *d*, *a*, D, E, must be adapted; this is shown in a large scale in *fig.* 1642.

1641





This is a condenser, in two pieces, made of thin sheet copper: D, the upper part, is a rectangular box, open at bottom, about 10 inches high, by 5 or 6 long and 2 wide; near to the side *a*, it is divided inside into two equal compartments, up to two-thirds of its height; by a partition, *b*, *b*, in order to make the vapours that issue from C pursue a downward and circuitous path. In each of its narrow sides, near the top, a short tube is soldered, at *d* and *a*; the former being fitted air-tight into the end of the nozzle of the retort, while the latter is closed with a cork traversed by a stiff iron probe, *e*, which passes through a small hole in the partition *b*, *b*, under *c*, and is employed to keep the tube C clear by its drill-shaped steel point. In one of the broad sides of the box D, near the top, a bit of pipe is soldered on at *c*, for receiving the end of a bent glass tube of safety, which dips its other and lower end into a glass containing naphtha. E, is the bottom copper box, with naphtha, which receives pretty closely the upper case, D, and is to be immersed in a cistern of cold water, containing lumps of ice.

In this process, carbonate of potash is obtained by calcination of the tartar, and this carbonate is then decomposed by the carbon, with formation of carbonic oxide gas and elimination of metallic potassium. For details of the process, and for precautions to be observed, see Watts's 'Dictionary of Chemistry.'

Pure potassium, thus procured, or by Davy's original method, by acting upon fused potash under a film of naphtha, with the negative wire of a powerful voltaic battery, is a soft metal, which can be cut, like wax, with a knife, and its newly-cut surface possesses great brilliancy. It is fluid at 120° F. At 50° it is malleable, and has the lustre of polished silver; at 32° it is brittle, with a crystalline fracture; and at a heat approaching to redness, it begins to boil, is volatilised, and converted into a green-coloured gas, which condenses into globules upon the surface of a cold body. Its specific gravity in the purest state is 0·865 at 60°. When heated in the air, it takes fire, and burns very vividly. It has a stronger affinity for oxygen than any other known substance; and is hence very difficult to preserve in the metallic state. At a high temperature it reduces almost every oxygenised body. When thrown upon water, it kindles, and moves about violently upon the surface, burning with a violet flame, till it be consumed; that is to say, converted into potash. When thrown upon a cake of ice, it likewise kindles, and melts a hole in it. If a globule of it be laid upon wet turmeric-paper, it takes fire, and runs about, marking its desultory paths with red lines. The flame observed in these cases is owing chiefly to hydrogen, for it is at the expense of the water that the potassium burns, potassuretted hydrogen being formed.

POTASSIUM, BROMIDE OF. A compound resembling iodide of potassium, and prepared by similar processes.

POTASSIUM, CHLORIDE OF. This salt may be obtained from sea-water or from kelp, but it is now generally prepared by washing *carnallite*, a double chloride of potassium and magnesium, from which the latter chloride is readily removed by water. Chloride of potassium occurs among the Stassfurt salts as a distinct mineral known as *Sylvine*. See CARNALLITE; POTASH; SYLVINE.

POTASSIUM, CYANIDE OF. See CYANIDES.

POTASSIUM, HYDRATE OF. See POTASH.

POTASSIUM, IODIDE OF. Iodide of potassium is usually prepared by digesting 2 parts of iodine, and 1 part of pure iron filings, in 10 parts of water, till they have combined to form a solution of a pale green colour, which is a solution of the iodide of iron. This solution is decomposed with exactly the requisite quantity of carbonate of potash, and iodide of potassium is held in solution, the iron salt being precipitated. The iodide is then crystallised out.

A more recent process consists in digesting 1 part of amorphous phosphorus in 40 parts of warm water, and adding 20 of dry iodine. To the solution, carbonate of baryta is first added, and then baryta-water; the phosphate of baryta is filtered off, and the solution of iodide of barium treated with sulphate of potash, when iodide of potassium and sulphate of baryta are obtained.

Iodide of potassium is much used in photography to obtain the iodide of silver; and for this purpose its purity is of great importance. The iodide of potassium of commerce frequently contains carbonate of potash, caustic potash, and the bromide and chloride of potassium.

POTASSIUM, OXIDE OF. See POTASH.

POTATO. (*Pomme de terre*, Fr.; *Kartoffel*, Ger.) The well-known tuber (underground stem) of the *Solanum tuberosum*.

Many methods have at different times been tried for preserving potatoes in an unchangeable state and always ready to be dressed into a wholesome and nutritious dish, but none with such success as the plan of Mr. Downes Edwards, for which he obtained a patent in August 1840. The potatoes, being first clean-washed, are boiled in water or steamed, till their skins begin to crack, then peeled, freed from their specks and eyes, and placed in an iron cylinder, tinned inside, and perforated with many holes one-eighth of an inch in diameter. The potatoes are forced through these by the pressure of a piston. The pulp is finally dried on well-tinned plates of copper, moderately heated by steam, into a granular meal. When this is mixed into a pulp with hot water, and seasoned with milk, &c., it forms a very agreeable food, like fresh mashed potatoes. See STARCH.

POTATO-STARCH. *English Arrowroot.* See STARCH.

POTATO-SUGAR. See SUGAR.

POTSTONE, or *Lapis ollaris* (*Topfstein*, Ger.), is an impure variety of steatite used in Germany for ornamental purposes. See TALC.

POT METAL. A metal composed of lead and copper, used for making pots.

POTTER'S ORE. Picked lumps of the sulphide of lead (galena). See LEAD.

POTTERY and **PORCELAIN**; EARTHENWARE, STONEWARE. (Engl. and Fr.; *Steingut*, *Porcellan*, Ger.) The French call the potter's art *céramique*, from the Greek noun *κέραμος*, an earthen pot, or *burned clay*. In reference to chemical constitution, there are only two genera of ceramic ware. The first consists of a fusible earthy mixture, along with an infusible, which, when combined, are susceptible of becoming semi-vitrified and translucent in the kiln. This constitutes true *porcelain* or chinaware; which is also called *hard* and *genuine*, or *tender* and *spurious*, according to the quality and quantity of the fusible ingredients. The *tender* or *soft* porcelain is an earthy body, which is covered with and penetrated by a transparent glaze. The second kind consists of an infusible mixture of earths, which is refractory in the kiln and continues opaque. This is *pottery*, properly so called; but it comprehends several subspecies, which graduate into each other by imperceptible shades of difference. To this head belong earthenware, stoneware, *fayence*, delft-ware, iron-stone china, &c.

The glazed bricks from Babylon—the enamelled tiles from the ruined cities of the Desert—and the glazed coffins from those Assyrian cities of the dead discovered by Mr. Kennett Loftus, prove, contrary to the received ideas, that the earliest attempts to make a compact earthenware, with a painted glaze, did not originate with the Arabians in Spain about the ninth century; but it is certain that the art passed thence into Majorca, in which island they were carried on with no little success. In the 14th century, these articles, and the art of imitating them, were highly prized by the Italians, under the name of Majolica, and *porcellana*, from the Portuguese word for a cup. The first manufactory of this ware possessed by them was erected at Faenza, in the ecclesiastical States, whence the French term *fayence* is derived. The body of the ware was usually a red clay, and the glaze was opaque, being formed of the oxides of lead and tin, along with potash and sand, which glaze was in all probability the discovery of Luca della Robbia, which he had found 'after experiments innumerable.' Bernard Palissy, about the middle of the 16th century, manufactured the Palissy ware —which is remarkable for its beautiful glaze, and the imitation of plants and animals —at Saintes, in France; and not long afterwards the Dutch produced a similar article, of substantial make, under the name of Delft-ware, but destitute of those graceful forms and paintings for which the ware of Faenza was distinguished.

The English East India Company was formed in 1600, and in 1631 they imported China ware into England. The Dutch, however, in 1586, appear to have traded in this true porcelain. There was naturally a desire to imitate this beautiful manufacture. In this Böttcher made the first advance in 1709; although it is now known that a porcelain of *soft* paste was made at Florence as early as 1580. Böttcher was working in the laboratory of Tschirnhaus, an alchemist, at Dresden, and it is stated that some crucibles prepared by him assumed the character of Chinese porcelain. Böttcher made first a red ware, but eventually, by employing white clays (*Kaolin*) which were found near Schneeberg in the Erzgebirge, he made a true porcelain at Meissen. Eventually the manufacture spread to Dresden, Munich, and other places, and the celebrated Sèvres Pottery was established.

In England, porcelain appears to have been experimentally manufactured at Fulham, by Dwight, as far back as 1671; but it was not produced in quantity until about 1730, when works were established at Bow, and these were soon afterwards followed by the factories of Chelsea, Derby, and Worcester. Porcelain with *hard* paste, however, was not produced in this country until Cookworthy's celebrated discovery of the Cornish china-clay and china-stone—a discovery which led to the foundation of the porcelain works of Plymouth and Bristol.

Coarse ware was manufactured in Staffordshire as early as, if not earlier, than 1500. Dr. Shaw says, 'there exist documents which imply that during many centuries considerable quantities of common culinary articles were manufactured of red, brown, and mottled pottery.'—*History of Staffordshire Potteries.*

It was in 1670 that a work for making earthenware of a coarse description, coated with a common lead-glaze (butter pots), was formed at Burslem, which may be considered as the germ of the vast potteries now established in Staffordshire. The manufacture was improved about the year 1690, by two Germans, the brothers Elers, who were compelled to leave the Potteries in 1710, and it is said they settled in Chelsea. The introduction of the use of salt for glazing took place in 1690 at Palmer's pottery at Bagnall. It is to the late Josiah Wedgwood that this country and the world at large are mainly indebted for the great modern advancement of the *ceramic* art. It was he who first erected magnificent factories, where every resource of mechanical and chemical science was made to co-operate with the arts of painting, sculpture, and statuary, in perfecting this valuable department of the industry of nations. So sound were his principles, so judicious his plans of procedure, and so ably have they been prosecuted by his successors in Staffordshire, and especially by the late Herbert Minton, that a population of upwards of 100,000 operatives now derives a comfortable subsistence within a district formerly bleak and barren, of 8 miles long by 6 broad, which contains 250 kilns, and is significantly called 'The Potteries.'

Of the Materials of Pottery, and their Preparation.

Clay.—The best clay from which the Staffordshire ware is made comes from Poole in Dorsetshire, and a second quality from near Newton in Devonshire; but both are well adapted for working, being refractory in the fire, and becoming very white when burnt. The clay is cleaned as much as possible by hand and freed from loosely adhering stones at the pits where it is dug. For the manufacture of porcelain, and of the finer kinds of earthenware, the china-clay is used. (See Clay.) In the factory the clay is cut to pieces, and then kneaded into a pulp with water, by engines; instead of being broken down with pickaxes, and worked with water by hand-paddles, in a square pit or water-tank, an old process, called *blunging*. The clay is now thrown into a cast-iron cylinder, 20 inches wide and 4 feet high, or into a cone 2 feet wide at top and 6 feet deep, in whose axis an upright shaft revolves, bearing knives as radii to the shaft. The knives are so arranged, that their flat sides lie in the plane of a spiral line; so that by the revolution of the shaft, they not only cut through everything in their way, but constantly press the soft contents of the cylinder or cone obliquely downwards, on the principle of a screw. Another set of knives stands out motionless, at right angles from the inner surface of the cylinder, and projects nearly to the central shaft, having their edges looking opposite to the line of motion of the revolving blades. Thus the two sets of slicing implements, the one active, and the other passive, operate like shears in cutting the clay into small pieces, while the active blades, by their spiral form, force the clay in its comminuted state out at an aperture at the bottom of the cylinder or cone, whence it is conveyed into a cylindrical vat, to be worked into a pap with water. This cylinder is tub-shaped, being about four times wider than it is deep. A perpendicular shaft turns also in the axis of this vat, bearing cross spokes, one below another, of which the vertical set on each side is connected by upright staves, giving the moveable arms the appearance of two or four opposite square paddle-boards revolving with the shaft. This wooden framework, or large *blunger*, as it is called, turns round amidst the water and clay lumps, so as to beat them into a fine pap, from which the stony and coarse sandy particles separate, and subside to the bottom. Whenever the pap has acquired a cream-consistenced uniformity, it is run off through a series of wire, lawn, and silk sieves, of different degrees of fineness, which are kept in continual agitation backwards and forwards by a crank mechanism; and thus all the grosser parts are completely separated, and hindered from entering into the composition of the ware. This clay-liquor is set aside in proper cisterns, and diluted with water to a standard density.

Flints.—These are obtained in great quantities from the chalk formations. See FLINTS.

Chert, which is a flinty substance, found in the Mountain Limestone, is also employed. This is calcined and ground. See CHERT.

Felspar. Used both in the body and in glazing. See FELSPAR.

Bone.—Bone-ashes, (phosphate of lime), also enters into the composition of pottery.

Steatite, or *Soap-stone,* is occasionally employed. See STEATITE.

China-stone.—A decomposed granite. See CHINA-STONE.

These may be regarded as the substances which enter into the body of the ware.

Clay alone cannot form a proper material for pottery, on account of its great contractility by heat, and the consequent cracking and splitting in the kiln of the vessels made of it; for which reason a siliceous substance incapable of contraction must enter into the body of pottery. For this purpose, ground flint, called flint-powder by the potters, is universally preferred. The nodules of flint extracted from the chalk formation are washed, heated red-hot in a kiln, like that for burning lime, and thrown in this state into water, by which treatment they lose their translucency, and become exceedingly brittle. They are then reduced to a coarse powder in a stamping-mill or a crushing-mill. The pieces of flint are laid on a strong grating, and pass through its meshes whenever they are reduced by the stamps to a certain state of comminution. This granular matter is now transferred to the proper flint-mill, which consists of a strong cylindrical wooden tub, bottomed with flat pieces of massive *chert,* or hornstone, over which are laid large flat blocks of similar chert, that are moved round over the others by strong iron or wooden arms projecting from an upright shaft made to revolve in the axis of the mill-tub. Sometimes the active blocks are fixed to these cross arms, and thus carried round over the passive blocks at the bottom. Into this cylindrical vessel a small stream of water constantly trickles, which facilitates the grinding motion and action of the stones, and works the flint-powder and water into a species of pap. Near the surface of the water there is a plug-hole in the side of the tub, by which the creamy-looking flint-liquor is run off from time to time, to be passed through lawn or silk sieves, similar to those used for the clay-liquor; while the particles that remain on the sieves are returned into the mill. This pap is also reduced to a standard density by dilution with water; whence the weight of dry siliceous earth present may be deduced from the measure of the liquor.

The standard clay- and flint-liquors are now mixed together, in such proportion by measure, that the flint-powder may bear to the dry clay the ratio of one to five, or occasionally one to six, according to the richness or plasticity of the clay; and the liquors are intimately incorporated in a revolving churn, similar to that employed for making the clay-pap. This mixture is next freed from its excess of water by evaporation in oblong stone troughs, called *slip-kilns*, bottomed with fire-tiles, under which a furnace-flue runs. The breadth of this evaporating trough varies from 2 to 6 feet; its length from 20 to 50; and its depth from 8 to 12 inches, or more.

By the dissipation of the water, and careful agitation of the pap, an uniform doughy mass is obtained; which, being taken out of the trough, is cut into cubical lumps. These are piled in heaps, and left in a damp cellar for a considerable time; that is, several months, in large manufactories. Here the dough suffers disintegration, promoted by a kind of fermentative action, due probably to some vegetable-matter in the water and the clay; for it becomes black, and exhales a fœtid odour. The argillaceous and siliceous particles get disintegrated also by the action of the water, in such a way that the ware made with old paste is found to be more homogeneous, finer grained, and not so apt to crack or to get disfigured in the baking, as the ware made with newer paste.

But this chemical comminution must be aided by mechanical operations; the first of which is called the potter's *slapping* or *wedging*. It consists in seizing a mass of clay in the hands, and, with a twist of both at once, tearing it into two pieces, or cutting it with a wire. These are again slapped together with force, but in a different direction from that in which they adhered before, and then dashed down on a board. The mass is once more torn or cut asunder at right angles, again slapped together, and so worked repeatedly for 20 or 30 times, which ensures so complete an incorporation of the different parts, that if the mass had been at first half black and half white clay, it would now be of a uniform grey colour. A similar effect is produced in some large establishments by a slicing machine, like that used for cutting down the clay lumps as they come from the pit.

In the axis of a cast-iron cylinder or cone, an upright shaft is made to revolve, from which the spiral-shaped blades extend, with their edges placed in the direction of rotation. The pieces of clay subjected to the action of these knives (with the reaction of fixed ones) are minced to small morsels, which are forced pell-mell by the screw-like pressure into an opening of the bottom of the cylinder or cone from which a horizontal pipe about 6 inches square proceeds. The dough is made to issue through this outlet, and is then cut into lengths of about 12 inches. These clay pillars or prisms are thrown back into the cylinder, and subjected to the same operation again and again, till the lumps have their particles perfectly blended together. This process may advantageously precede their being set aside to ripen in a damp cellar. In France the earthenware dough is not worked in such a machine; but after being beat with wooden mallets, a practice common also in England, it is laid down on a clean floor, and a workman is set to tread upon it with naked feet for a considerable time, walking in a spiral direction from the centre to the circumference, and from the circumference to the centre. In Sweden, and also in China (to judge from the Chinese paintings which represent their manner of making porcelain), the clay is trodden to a uniform mass by oxen. It is afterwards, in all cases, kneaded like baker's dough, by folding back the cake upon itself, and kneading it out alternately.

Although we have abundant evidence proving to us the importance of the so-called fermenting process, of the treading operation, and of the slapping, we are not in possession of any explanation, which is in the slightest degree reliable, as to any one of the changes which may be effected in the mass by these manipulations.

The basis of the English earthenware is a clay, brought from Dorsetshire and Devonshire, which lies at the depth of from 25 to 30 feet beneath the surface. It is composed of about 24 parts of alumina and 76 of silica, with other ingredients in very small proportions. This clay is very refractory in high heats, a property which joined to its whiteness when burned, renders it peculiarly valuable for pottery. It is also the basis of all the yellow biscuit-ware called *cream colour*, and in general of what is called the *printing body*; as also for the semi-vitrified ware of Wedgwood's invention, and of the tender (soft) porcelain.

The constituents of earthenware are, Dorsetshire clay, the powder of calcined flints, and of the decomposed granite called Cornish stone. The proportions are varied by the different manufacturers. The following are those generally adopted in one of the principal establishments of Staffordshire:—

For *cream colour* ware,	Silex or ground flints	20 parts.
	Clay	100 „
	Cornish stone	2 „

Composition of the Paste for receiving the Printing Body under the Glaze.

For this purpose the proportions of the flint and the felspar must be increased. The substances are mixed separately with water into the consistence of a thick cream, which weighs per pint, for the flints 32 ounces, and for the Cornish stone 28. The china-clay is added to the same mixture of flint and felspar, when a finer pottery or porcelain is required. That clay-cream weighs 24 ounces per pint. These 24 ounces in weight are reduced to one-third of their bulk by evaporation. The pint of dry porcelain-clay weighs 17 ounces, and in its first pasty state 24, as just stated. The dry flint-powder weighs 14½ ounces per pint; which when made into a cream weighs 32 ounces. To 40 measures of Teignmouth clay-cream there are added,

13 measures of flint-liquor.
12 „ „ porcelain clay ditto.
1 „ „ Cornish stone ditto.

The whole are well mixed by proper agitation, half dried in the *troughs* of the slip-kiln, and then subjected to the machine for cutting up the clay into junks. The above paste, when baked, is very white, hard, sonorous, and susceptible of receiving all sorts of impressions from the paper engravings. When the silica is mixed with the clay in the above proportions, it forms a compact ware, and the impression remains fixed between the biscuit and the glaze, without communicating to either any portion of the tint of the metallic colour employed in the engraver's press. The felspar gives strength to the biscuit, and renders it sonorous after being baked; while the china-clay has the double advantage of imparting an agreeable whiteness and great closeness of grain.

We must now proceed to a consideration of the manufacture. The clay being prepared, is submitted to the potter, who employs at the present day a wheel of the same description as that used in the days of Moses.

Throwing is performed upon a tool called the potter's lathe. This consists of an upright iron shaft, about the height of a common table, on the top of which is fixed, by its centre, a horizontal disc or circular piece of wood, of an area sufficiently great for the largest vessel to stand upon. The lower end of the shaft is pointed, and runs in a conical step, and its collar, a little below the top-board, being truly turned, is embraced in a socket attached to the wooden frame of the lathe. The shaft has a pulley fixed upon it, with grooves for 3 speeds, over which an endless band passes from a fly-wheel, by whose revolution any desired rapidity of rotation may be given to the shaft and its top-board. This wheel, when small, may be placed alongside, as in the turner's lathe, and then it is driven by a treadle and crank; or when of larger dimensions, it is turned by the arms of a labourer.

1643

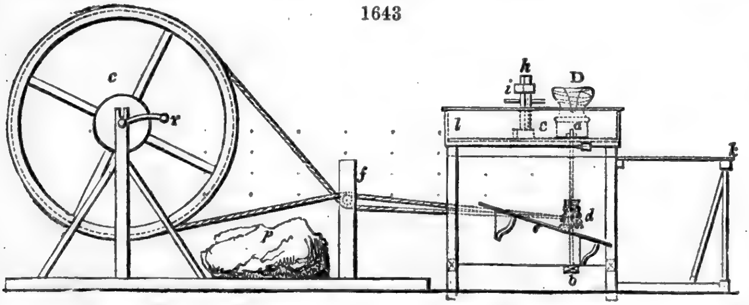


Fig. 1643 is the profile of the ordinary potter's lathe, for blocking-out round ware. c is the table or tray; *a* is the head of the lathe, with its horizontal disc; *a, b,* is the upright shaft of the head; *d,* pulleys with several grooves of different diameters, fixed upon the shaft, for receiving the driving-cord or band; *k* is a bench upon which the workman sits astride; *e,* the treadle foot-board; *l* is a ledge-board, for catching the shavings of clay which fly off from the lathe; *h* is an instrument, with a slide-nut *i,* for measuring the objects in the blocking-out; *c* is the fly-wheel, with its winch-handle, *r,* turned by an assistant; the sole-frame is secured in its place by the heavy stone *p*; *f* is the oblong guide-pulley, having also several grooves for converting the vertical movement of the fly-wheel into the horizontal movement of the head of the lathe.

D is one of the intermediate forms given by the potter to the ball of clay, as it revolves upon the head of the lathe.

In large potteries, the whole of the lathes, both for throwing and turning, are put in motion by a steam-engine. The vertical spindle of the lathe has a bevel wheel on it, which works in another bevel-toothed wheel fixed to a horizontal shaft. This shaft is provided with a long conical wooden drum, from which a strap ascends to a similar conical drum on the main lying shaft. The apex of the one cone corresponds to the base of the other, which allows the strap to retain the same degree of tension, while it is made to traverse horizontally, in order to vary the speed of the lathe at pleasure. When the belt is at the base of the driving-cone, it works near the vertex of the driven one, so as to give a maximum velocity to the lathe, and *vice versâ.*

During the throwing of any article, a separate mechanism is conducted by a boy, which makes the strap move parallel to itself along these conical drums, and nicely regulates the speed of the lathe. When the strap runs at the middle of the cones, the velocity of each shaft is equal. By this elegant contrivance of parallel cones reversed, the velocity rises gradually to its maximum, and returns to its minimum or slower motion when the workman is about to finish the article thrown. The strap is then transferred to a pair of loose pulleys, and the lathe stops. The vessel is now cut off at the base with a small wire; is dried, turned on a power-lathe, and polished as above described.

The same degree of dryness which admits of the clay being turned on the lathe, also suits for fixing on the handles and other appendages to the vessels. The parts to be attached being previously prepared, are joined to the circular work by means of a thin paste, which the workmen call *slip*, and the seams are then smoothed off with a wet sponge. They are now taken to a stove-room heated to 80° or 90° F., and fitted up with a great many shelves. When they are fully dried, they are smoothed over with a small bundle of hemp, if the articles be fine, and are then ready for the kiln, which is to convert the tender clay into the hard *biscuit.*

At a certain stage of the drying, called the *green state*, the ware possesses a greater tenacity than at any other, till it is baked. It is then taken to another lathe, called the *turning lathe*, where it is attached by a little moisture to the vertical face of a wooden chuck, and turned nicely into its proper shape with a very sharp tool, which also smooths it. After this it is slightly burnished with a smooth steel surface. A great variety of pottery wares, however, cannot be fashioned on the lathe, as they are not of a circular form. These are made by two different matters, the one called *press-work*, and the other *casting*. The press-work is done in moulds made of Paris plaster, the one half of the pattern being formed in the one side of the mould, and the other half in the other side: these moulding-pieces fit accurately together. All vessels of an oval form, and such as have flat sides, are made in this way. Handles of tea-pots, and fluted solid rods of various shapes, are formed by pressure also; viz. by squeezing the dough contained in a pump-barrel through different-shaped orifices at its bottom, by working a screw applied to the piston-rod. The worm-shaped dough, as it issues, is cut to proper lengths, and bent into the desired form. Tubes may be also made on the same pressure principle, only a tubular opening must be provided in the bottom-plate of the clay-forcing pump. The temperature of the various rooms in a pottery is as follows:—

Plate-makers' hothouse	108° Fahr.
Dish-makers' hothouse	106 „
Printers' shop	90 „
Throwers' hothouse	98 „

The branches against which the temperature of the hothouse is placed require that heat for drying their work and getting it off their moulds. The outer shops in which they work may be from five to ten degrees less.

The other method of fashioning earthenware articles is called *casting*, and is, perhaps, the most elegant for such as have an irregular shape. This operation consists in pouring the clay, in the state of pap or slip, into plaster-moulds, which are kept in a desiccated state. These moulds, as well as the pressure ones, are made in halves, which nicely correspond together. The slip is poured in till the cavity is quite full, and is left in the mould for a certain time, more or less, according to the intended thickness of the vessel. The absorbent power of the plaster soon abstracts the water, and makes the coat of clay in contact with it quite doughy and stiff, so that the part still liquid being poured out, a hollow shape remains, which when removed from the mould constitutes the half of the vessel, bearing externally the exact impress of the mould. The thickness of the clay varies with the time that the paste has stood upon the plaster. These *cast* articles are dried to the green state, like the preceding, and then joined accurately with *slip.* Imitations of flowers and foliage are elegantly executed in this way. This operation, which is called *furnishing*, requires very delicate and dexterous manipulation.

The saggers for the unglazed coloured ware should be covered inside with a glaze composed of 12 parts of common salt and 30 of potash, or 6 parts of potash and 14 of salt; which may be mixed with a little of the common enamel for the glazed pottery saggers. The bottom of each sagger has some bits of flints sprinkled upon it, which become so adherent after the first firing as to form a multitude of little prominences for setting the ware upon, when this does not consist of plates. It is the duty of the workmen belonging to the glaze-kiln to make the saggers during the intervals of their work; or if there be a relay of hands, the man who is not firing makes the saggers.

When the ware is sufficiently dry, and in sufficient quantity to fill a kiln, the next process is placing the various articles in the baked fire-clay vessels, which may be either of a cylindrical or oval shape; called *gazettes*, Fr.; *Kapseln*, Ger. These are from 6 to 8 inches deep, and from 12 to 18 inches in diameter. When packed full of the dry ware, they are piled over each other in the kiln. The bottom of the upper sagger forms the lid of its fellow below; and the junction of the two is luted with a ring of soft clay applied between them. These dishes protect the ware from being suddenly and unequally heated, and from being soiled by the smoke and vapours of the fuel. Each pile of saggers is called a *bung*.

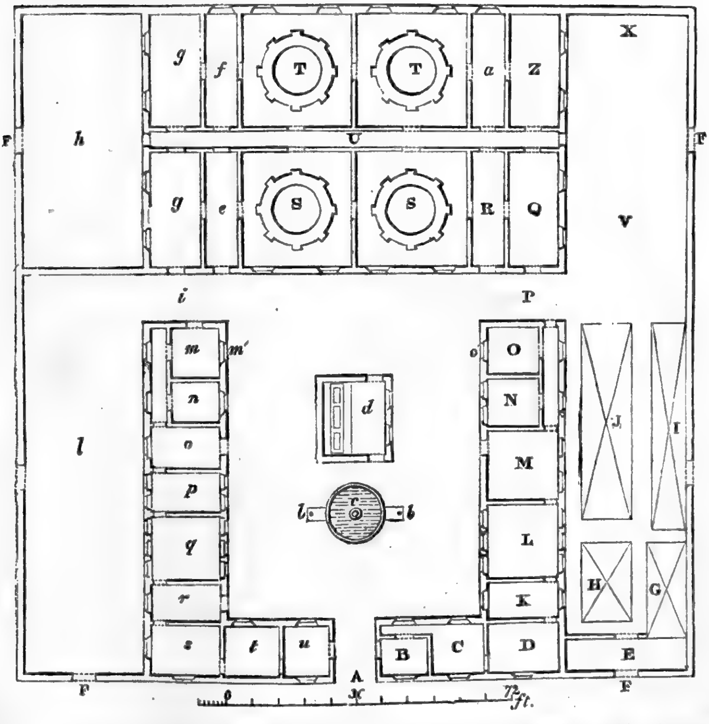
Plan of an English Pottery.

A pottery should be placed by the side of a canal or navigable river, because the articles manufactured do not well bear land-carriage.

A Staffordshire pottery is usually built as a quadrangle, each side being about 100 feet long, the walls 10 feet high, and the ridge of the roof 5 feet more. The base of the edifice consists of a bed of bricks, 18 inches high and 16 inches thick; upon which a mud wall in a wooden frame, called *pisé*, is raised. Cellars are formed in front of the buildings, as depôts for the pastes prepared in the establishment. The wall of the yard or court is 9 feet high and 18 inches thick.

A, *fig*. 1644, is the entrance door; B, the porter's lodge; C, a particular warehouse; D, workshop of the plaster-moulder; E, the clay depôt; F, F, large gates, 6 feet 8 inches high; G, the winter evaporation-stove; H, the shop for sifting the paste-liquors; I, sheds for the paste-liquor tubs; J, paste-liquor pits; K, workshop for the moulder of hollow ware; L, ditto of the dish or plate moulder; M, the plate drying-stove N, workshop of the biscuit-printers; O, ditto of the biscuit, with *o′*, a long window; P, passage leading to the paste-liquor pits; Q, biscuit warehouse; R, place where the biscuit is cleaned as it comes out of the biscuit-kilns, S, S; T, T, enamel- or

1644



glaze-kilns; U, long passage; V, space left for supplementary workshops; X, space appointed as a depôt for the sagger fire-clay, as also for making the saggers; Z, the workshop for applying the glaze-liquor to the biscuits; *a*, apartment for cleaning the glazed ware; *b*, *b*, pumps; *c*, basin; *d*, muffles; *e*, warehouse for the finished stoneware; *f*, that of the glazed goods; *g*, *g*, another warehouse; *h*, a large space for the smith's forge, carpenter's shop, packing room, depôt of clays, saggers, &c. The packing and loading of the goods are performed in front of the warehouse, which has two outlets, in order to facilitate the work; *i*, a passage to the court or yard; *l*, a space for the wooden sheds for keeping hay, clay, and other miscellaneous articles; *m*, room for putting the biscuit into the saggers; *m'*, a long window; *n*, workshop with lathes and fly-wheels; *o*, drying-room; *p*, room for mounting or furnishing the pieces; *q*, repairing room; *r*, drying room of the goods roughly turned; *s*, rough turning or blocking-out room; *t*, room for beating the paste or dough; *u*, counting-house.

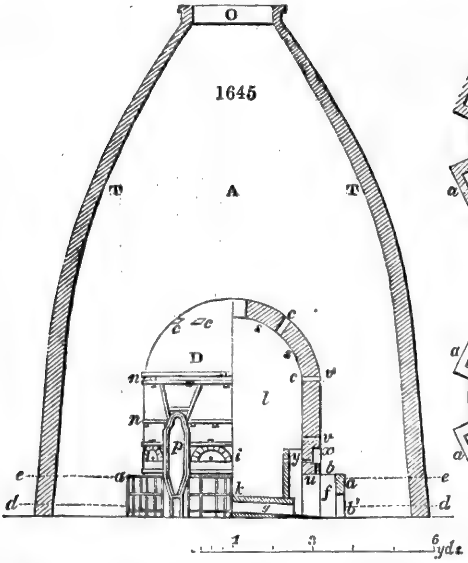
Pottery Kiln of Staffordshire.

Figs. 1645, 1646, 1647, 1648, 1649, represent the kiln for baking the biscuit, and also for running the glaze, in the English potteries.

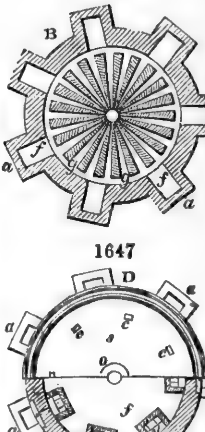
a, *a*, *figs.* 1645, 1646, 1647, are the furnaces which heat the kiln; of which *b*, in *fig.* 1645, are the upper mouths, and *b'* the lower; the former being closed more or less by the fire-tile *z*, shown in *fig.* 1649.

f is one fireplace; for the manner of distributing the fuel in it, see *fig.* 1649.

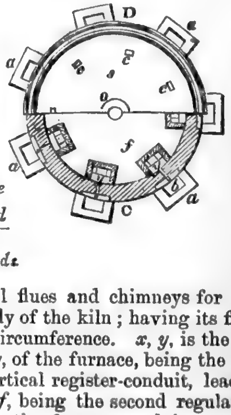
1645



1646

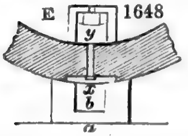


1647



g, *y*, *figs.* 1645, 1649, are the horizontal and vertical flues and chimneys for conducting the flame and smoke. *l* is the laboratory, or body of the kiln; having its floor, *k*, sloping slightly downwards from the centre to the circumference. *x*, *y*, is the slit of the horizontal register leading to the chimney-flue, *y*, of the furnace, being the first regulator; *x*, *u*, is the vertical register-conduit, leading to the furnace or mouth *f*, being the second regulator; *v* is the register-slit above the furnace, and its vertical flue leading into the body of the kiln; *v'*, *c*, slit for regulating flue at the shoulder of the kiln; *i* is an arch which supports the walls of the kiln, when the furnace is under repair; *c*, *c*, are small flues in the vault *s* of the laboratory. *h*, *fig.* 1646, is the central flue, called *lunette*, of the laboratory.

1648



T, T, is the conical tower or *howell*, strengthened with a series of iron hoops. O is the great chimney or *lunette* of the tower; *p* is the door of the laboratory, bound inside with an iron frame.

A, is the complete kiln and *howell*, with all its appurtenances.

B, *fig.* 1646, is the plan at the level *d, d,* of the floor, to show the arrangement and distribution of all the horizontal flues, both circular and radiating.

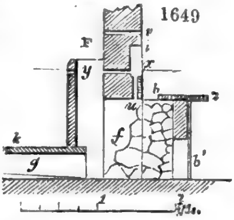
C, *fig.* 1647, is a plan at the level *e, e,* of the upper mouths *b*, of the furnaces, to show the disposition of the fireplaces of the vertical flues, and of the horizontal registers, or peep-holes.

D, *fig.* 1647, is a bird's-eye view of the top of the vault or dome *s*, to show the disposition of the vent-holes, *o, c.*

E, *fig.* 1648, is a detailed plan at the level *c, c,* of one furnace and its dependencies.

F, *fig.* 1649, is a transverse section, in detail, of one furnace and its dependencies.

1649



The same letters indicate the same objects in all the figures.

Charging of the kiln.—The saggers are piled up first in the space between each of the upright furnaces, till they rise to the top of the flues. These contain the smaller articles. Above this level large fire-tiles are laid, for supporting other saggers, filled with teacups, sugar-basins, &c. In the bottom part of the pile, within the preceding, the same sorts of articles are put; but in the upper part all such articles are placed as require a high heat. Four piles of small saggers, with a middle one 10 inches in height, complete the charge. As there are 6 piles between each furnace, and as the biscuit-kiln has 8 furnaces, a charge consequently amounts to 48 or 50 *bungs*, each composed of from 18 to 19 saggers. The inclination of the bungs ought always to follow the form of the kiln, and should therefore tend towards the centre, lest the strong draught of the furnaces should make the saggers fall against the walls of the kiln, an accident apt to happen were these piles perpendicular. The last sagger of each bung is covered with an unbaked one, three inches deep, in place of a round lid. The watches are small cups, of the same biscuit as the charge, placed in saggers, four in number, above the level of the flue-tops. They are taken hastily out of the saggers, lest they should get smoked, and are thrown into cold water.

When the charging is completed, the firing is commenced, with coal of the best quality. The management of the furnaces is a matter of great consequence to the success of the process. No greater heat should be employed for some time than may be necessary to agglutinate the particles which enter into the composition of the paste, by evaporating all the humidity; and the heat should never be raised so high as to endanger the fusion of the ware, which would make it very brittle.

Whenever the mouth or door of the kiln is built up, a child prepares several fires in the neighbourhood of the *howell*, while a labourer transports in a wheelbarrow a supply of coals, and introduces into each furnace a number of lumps. These lumps divide the furnace into two parts; those for the upper flues being placed above, and those for the ground flues below, which must be kept unobstructed.

The fire-mouths being charged, they are kindled to begin the baking, the regulator tile, *z, fig.* 1649, being now opened; an hour afterwards the bricks at the bottom of the furnace are stopped up. The fire is usually kindled at 6 o'clock in the evening, and progressively increased till 10, when it begins to gain force, and the flame rises half-way up the chimney. The second charge is put in at 8 o'clock, and the mouths of the furnaces are then covered with tiles; by which time the flame issues through the vent of the tower. An hour afterwards a fresh charge is made; the tiles *z*, which cover the furnaces, are slipped back; the cinders are drawn to the front, and replaced with small coal. About half-past 11 o'clock the kiln-man examines his furnaces, to see that their draught is properly regulated. An hour afterwards a new charge of coal is applied; a practice repeated hourly till 6 o'clock in the morning. At this moment he takes out his first *watch*, to see how the baking goes on. It should be at a very pale-red heat; but the watch of 7 o'clock should be a deeper red. He removes the tiles from those furnaces which appear to have been burning too strongly, or whose flame issues by the orifices made in the shoulder of the kiln; and puts tiles upon those which are not hot enough. The flames glide along briskly in a regular manner. At this period he draws out the watches every quarter of an hour, and compares them with those reserved from a previous standard kiln; and if he observes a similarity of appearance, he allows the furnaces to burn a little longer; then opens the mouths carefully and by slow degrees; so as to lower the heat and finish the round.

The baking usually lasts from 40 to 42 hours; in which time the biscuit-kiln may consume 14 tons of coals; of which four are put in the first day, seven the next day and following night, and the last four give the strong finishing heat.

Emptying the kiln.—The kiln is allowed to cool very slowly. On taking the ware out of the saggers, the biscuit is not subjected to friction, as in the foreign potteries, because it is smooth enough; but is immediately transported to the place where it is to be dipped in the glaze- or enamel-tub. A child makes the pieces ring, by striking with the handle of the brush, as he dusts them, and then immerses them into the glaze-cream; from which tub they are taken out by the enameller, and shaken in the air. The tub usually contains no more than 4 or 5 inches depth of the glaze, to enable the workman to pick out the articles more readily, and to lay them upon a board, whence they are taken by a child to the glaze-kiln.

OF PORCELAIN.

Porcelain is a kind of pottery ware whose paste is fine grained, compact, very hard, and faintly translucid; and whose biscuit softens slightly in the kiln. Its ordinary whiteness cannot form a definite character, since there are porcelain pastes variously coloured. There are two species of porcelain, very different in their nature, the essential properties of which it is of consequence to establish; the one is called *hard*, and the other *tender* or *soft*: important distinctions, the neglect of which has introduced great confusion into many treatises on this elegant manufacture.

Hard porcelain is essentially composed, first, of a natural clay containing some silica, infusible, and preserving its whiteness in a strong heat; this is almost always a true kaolin; secondly, of a flux, consisting of silica and alkali, composing a quartzose felspar rock, called *pe-tun-tse.* The glaze of this porcelain, likewise earthy, admits of no metallic substance.

The biscuit of the hard porcelain made at the French national manufactory of Sèvres is generally composed of a kaolin-clay, and of a decomposed felspar-rock; analogous to the china-clay of Cornwall and Cornish stone. Both of the above French materials come from Saint Yrieux-la-Perche, near Limoges.

After many experiments, the following composition has been adopted for the *service paste* of the Royal manufactory of Sèvres; that is, for all the ware which is to be glazed: silica, 59; alumina, 35·2; potash, 2·2; lime, 3·3. The conditions of such a compound are pretty nearly fulfilled by taking from 63 to 70 of the washed kaolin or china-clay, 22 to 15 of the felspar, nearly 10 of flint-powder, and about 5 of chalk. The glaze is composed solely of solid felspar, calcined, crushed, and then ground fine at the mill. This rock pretty uniformly consists of silica 73, alumina 16·2, potash 8·4, and water 0·6.

The kaolin is washed at the pit, and sent in this state to Sèvres, under the name of *decanted earth.* At the manufactory it is washed and elutriated with care; and its slip is passed through fine sieves. This forms the plastic, infusible, and opaque ingredient to which the substance must be added which gives it a certain degree of fusibility and semi-transparency. The felspar-rock used for this purpose should contain neither dark mica nor iron, either as an oxide or sulphide. It is calcined to make it crushable under stamp-pestles driven by machinery, and then ground fine in hornstone (chert) mills. This pulverulent matter being diffused through water, is mixed in certain proportions regulated by its quality, with the argillaceous slip. The mixture is deprived of the chief part of its water in shallow plaster pans without heat; and the resulting paste is set aside to ripen, in damp cellars, for many months.

When wanted for use, it is placed in hemispherical pans of plaster, which absorb the redundant moisture; after which it is divided into small lumps, and completely dried. It is next pulverised, moistened a little, laid on a floor, and trodden upon by a workman marching over it with bare feet in every direction; the parings and fragments of soft moulded articles being intermixed, which improve the plasticity of the whole. When sufficiently tramped, it is made up into masses of the size of a man's head, and kept damp till required.

The dough is now in a state fit for the potter's lathe; but it is much less plastic than earthenware paste, and is more difficult to fashion into the various articles; and hence one cause of the higher price of porcelain.

The round plates and dishes are shaped on plaster-moulds; but sometimes the paste is laid on as a crust, and at others it is turned into shape on the lathe. When a crust is to be made, a moistened sheep-skin is spread on a marble table; and over this the dough is extended with a rolling-pin, supported on two guide-rules. The crust is then transferred over the plaster-mould by lifting it upon the skin; for it wants tenacity to bear raising by itself. When the piece is to be fashioned on the lathe, a lump of the dough is thrown on the centre of the horizontal wooden disc, and turned into form as directed in treating of earthenware, only it must be left much thicker than in its finished state. After it dries to a certain degree on the plaster-mould, the workman replaces it on the lathe, by moistening it on its base with a wet sponge, and finishes its form with an iron tool. A good workman at Sèvres makes no more than from 15 to 20 porcelain plates in a day; whereas an English potter, with two boys, makes from 1,000 to 1,200 plates of earthenware in the same time. The pieces, which are not round, are shaped in plaster-moulds, and finished by hand. When the articles are very large, as wash-hand basins, salads, &c., a flat cake is spread above a skin on the marble slab, which is then applied to the mould with the sponge, as for plates; and they are finished by hand.

The projecting pieces, such as handles, beaks, spouts, and ornaments, are moulded and adjusted separately; and are cemented to the bodies of china-ware with slip, or porcelain dough thinned with water. In fact, the mechanical processes with porcelain and the finer stoneware are substantially the same; only they require more time and greater nicety. The least defect in the fabrication, the smallest bit added, an unequal pressure, the cracks of the moulds, although well repaired, and seemingly effaced in the clay shape, re-appear after it is baked. The articles should be allowed to dry very slowly; if hurried but a little, they are liable to be spoiled. When quite dry, they are taken to the kiln.

The kiln for hard porcelain at Sèvres is a kind of tower in two flats, constructed of fire-bricks; and resembles, in other respects, the earthenware kilns already figured and described. The fuel is young aspen wood, very dry, and cleft very small; it is put into the apertures of the four outside furnaces or fire-mouths, which discharge their flames into the inside of the kiln; each floor being closed in above, by a dome pierced with holes. The whole is covered in by a roof with an open passage, placed at a proper distance from the uppermost dome. There is, therefore, no chimney proper so called.

The raw pieces are put into the upper floor of the kiln; where they receive a heat of about the 60th degree of Wedgwood's pyrometer, and a commencement of baking, which, without altering the shape, or causing a perceptible shrinking of their bulk, makes them completely dry, and gives them sufficient solidity to bear handling. By this preliminary baking, the clay loses its property of forming a paste with water; and the pieces become fit for receiving the glazing coat, as they may be dipped in water without risk of breakage.

The glaze of hard porcelain is a felspar rock; this being ground to a very fine powder, is worked into a paste with water mingled with a little vinegar. All the articles are dipped into this milky liquid for an instant; and as they are very porous they absorb the water greedily, whereby a layer of the felspar-glaze is deposited on their surface, in a nearly dry state, as soon as they are lifted out. Glaze-pap is afterwards applied with a hair-brush to the projecting edges, or any points where it has not taken; and the powder is then removed from the part on which the article is to stand, lest it should get fixed to its support in the fire. After these operations, it is replaced in the kiln, to be completely baked.

The articles are put into saggers, like those of fine stoneware; and this operation is one of the most delicate and expensive in the manufacture of porcelain. The saggers are made of the plastic or potter's clay of Abondant, to which about a third part of cement of broken saggers has been added.

As the porcelain pieces soften somewhat in the fire, they cannot be set above each other, even were they free from glaze; for the same reason they cannot be baked on tripods, several of them being in one case, as is done with stoneware. Every piece of porcelain requires a sagger for itself. They must, moreover, be placed on a perfectly flat surface, because in softening they would be apt to conform to the irregularities of a rough one. When, therefore, any piece, a soup-plate for example, is to be *saggered*, there is laid on the bottom of the case a perfectly true disc or round cake of stoneware, made of the sagger material, and it is secured in its place on three small props of a clay-lute consisting of potter's clay mixed with a great deal of sand. When the cake is carefully levelled, it is moistened, and dusted over with sand, or coated with a film of fire-clay slip, and the porcelain is carefully set on it. The sand or fire-clay hinders it from sticking to the cake. Several small articles may be set on the same cake, provided they do not touch one another.

The saggers containing the pieces thus arranged are piled up in the kiln over each other, in the columnar form, till the whole space be occupied; leaving very moderate intervals between the columns to favour the draught of the fires. The whole being arranged with these precautions and several others too minute to be specified here, the door of the kiln is built up with three rows of bricks, leaving merely an opening 8 inches square, through which there is access to a sagger with the nearest side cut off. In this sagger are put fragments of porcelain intended to be withdrawn from time to time, in order to judge of the progress of the baking. These are called trial-pieces or watches (*montres*). This opening into the watches is closed by a stopper of stoneware.

The firing begins by throwing into the furnace-mouths some pretty large pieces of white wood; and the heat is maintained for about 15 hours, gradually raising it by the addition of a larger quantity of the wood, till at the end of that period the kiln has a cherry-red colour within. The heat is now greatly increased by the operation termed *covering the fire.* Instead of throwing billets vertically into the four furnaces, there is placed horizontally on the openings of these furnaces, aspen wood of a sound texture, cleft small, laid in a sloping position. The brisk and long flame which it yields dips into the tunnels, penetrates the kiln, and circulates round the sagger-piles. The heat augments rapidly, and at the end of 13 or 15 hours of this firing the interior of the kiln is so white that the watches can hardly be distinguished. The draught, indeed, is so rapid at this time, that one may place his hand on the slope of the wood without feeling incommoded by the heat. Everything is consumed, no small charcoal remains, smoke is no longer produced, and even the wood-ash is dissipated. It is obvious that the kiln and the saggers must be composed of a very refractory clay, in order to resist such a fire. The heat in the Sèvres kilns mounts as high as the 134th degree of Wedgwood.

At the end of 15 or 20 hours of the great fire, that is, after from 30 to 36 hours' firing, the porcelain is baked; as is ascertained by taking out and examining the watches. The kiln is suffered to cool during 3 or 4 days, and is then opened and discharged. The sand strewed on the cakes to prevent the adhesion of the articles to them, gets attached to their sole, and is removed by friction with a hard sandstone; an operation which one woman can perform for a whole kiln in less than 10 days; and is the last applied to hard porcelain, unless it needs to be returned into the hot kiln to have some defects repaired.

The materials of fine porcelain are very rare; and there would be no advantage in making a grey-white porcelain with coarser and somewhat cheaper materials, for the other sources of expense above detailed, and which are of most consequence, would still exist; while the porcelain, losing much of its brightness, would lose the main part of its value.

Its pap or dough, which requires tedious grinding and manipulation, is also more difficult to work into shapes, in the ratio of 80 to 1, compared to fine earthenware. Each porcelain plate requires a separate sagger; so that 12 occupy in the kiln a space sufficient for at least 38 earthenware plates. The temperature of a hard porcelain kiln being very high, involves a proportionate consumption of fuel and waste of saggers. With 40 cubic meters of wood, 12,000 earthenware plates may be completely fired, both in the biscuit- and glaze-kilns; while the same quantity of wood would bake at most only 1,000 plates of porcelain.

The process of bisque firing is as follows: the ware being finished from the hands of the potter is brought by him upon boards to the 'green-house,' so called from its being the receptacle for ware in the 'green' or unfired state. It is here gradually dried for the ovens; when ready it is carried to the 'sagger-house' in immediate connection with the oven in which it is to be fired, and here it is placed in the 'saggers:' these are boxes made of a peculiar kind of clay (a native marl) previously fired, and infusible at the heat required for the ware, and of form suited to the articles they are to contain. A little dry, pounded flint is scattered between pieces of china, and sand between earthenware, to prevent adhesion. The purpose of the sagger is to protect the ware from the flames and smoke, and also for its security from breakage, as in the clay state it is exceedingly brittle, and when dry, or what is called 'white,' requires great care in the handling. A plate sagger will hold twenty plates placed one on the other of earthenware, but china plates are fired separately in 'setters' made of their respective forms. The 'setters' for china plates and dishes answer the same purpose as the saggers, and are made of the same clay. They take in one dish or plate each, and are 'reared' in the oven in 'bungs' one on the other.

The hovels in which the ovens are built form a very peculiar and striking feature of the pottery towns, and forcibly arrest the attention and excite the surprise of the stranger, resembling as they closely do a succession of gigantic beehives. They are constructed of bricks about 40 feet in diameter, and about 35 feet high, with an aperture at the top for the escape of the smoke. The 'ovens' are of a similar form, about 22 feet diameter, and from 18 to 21 feet high, heated by fireplaces or 'mouths,' about nine in number, built externally around them. Flues in connection with these converge under the bottom of the oven to a central opening, drawing the flames to this point, where they enter the oven; other flues termed 'bags' pass up the internal sides to the height of about 4 feet, thus conveying the flames to the upper part.

When 'setting in' the oven, the firemen enter by an opening in the side, carrying the saggers with the ware placed as described; these are piled one upon another, from bottom to top of the oven, care being taken to arrange them so that they may receive the heat (which varies in different parts) most suited to the articles they contain. This being continued till the oven is filled, the aperture is then bricked up. The firing of earthenware bisque continues sixty hours, and of china forty-eight.

The quantity of coals necessary for a 'bisque' oven is from 16 to 20 tons; for a 'glost' oven from 4½ to 6 tons.

The ware is allowed to cool for two days, when it is drawn in the state technically called 'biscuit' or bisque, and is then ready for 'glazing,' except when required for printing or a common style of painting, both of which processes are done on the bisque prior to being 'glazed.'

Tender porcelain, or soft china-ware, is made with a vitreous frit, rendered less fusible and opaque by an addition of white marl or bone-ash. The frit is, therefore, first prepared. This, at Sèvres, is a composition, made with some nitre, a little sea salt, Alicant barilla, alum, gypsum, and much siliceous sand or ground flints. That mixture is subjected to an incipient pasty fusion in a furnace, where it is stirred about to blend the materials well; and thus a very white spongy frit is obtained. It is pulverised, and to every three parts of it, one of the white marl of Argenteuil is added; and when the whole are well ground, and intimately mixed, the paste of tender porcelain is formed.

As this paste has no tenacity, it cannot bear working till a mucilage of gum or black soap be added, which gives it a kind of plasticity, though even then it will not bear the lathe. Hence it must be fashioned in the press, between two moulds of plaster. The pieces are left thicker than they should be; and when dried, are finished on the lathe with iron tools.

In this state they are baked, without any glaze being applied; but as this porcelain softens far more during the baking than the hard porcelain, it needs to be supported on every side. This is done by baking on earthen moulds all such pieces as can be treated in this way, namely, plates, saucers, &c. The pieces are reversed on these moulds, and undergo their shrinkage without losing their form. Beneath other articles, supports of a like paste are laid, which suffer in baking the same contraction as the articles, and of course can serve only once. In this operation saggers are used, in which the pieces and their supports are fired.

The kiln for the tender porcelain at Sèvres is absolutely similar to that for the common earthenware; but it has two floors; and while the biscuit is baked in the lower story, the glaze is fused in the upper one; which causes considerable economy of fuel. The glaze of soft porcelain is a species of glass or crystal prepared on purpose. It is composed of flint, siliceous sand, a little potash or soda, and about two-fifth parts of lead oxide. This mixture is melted in crucibles or pots beneath the kiln. The resulting glass is ground fine, and diffused through water mixed with a little vinegar to the consistence of cream. All the pieces of biscuit are covered with this glazy matter, by pouring this slip over them, since their substance is not absorbent enough to take it on by immersion.

The pieces are encased once more each in a separate sagger, but without any supports; for the heat of the upper floor of the kiln, though adequate to melt the glaze, is not strong enough to soften the biscuit. But as this first vitreous coat is not very equal, a second one is applied, and the pieces are returned to the kiln for the third time. See STONE, ARTIFICIAL, for a view of this kiln.

The manufacture of soft porcelain is longer and more difficult than that of hard; its biscuit is dearer, although the raw materials may be found everywhere; and it furnishes also more refuse. Many of the pieces split asunder, receive fissures, or become deformed in the biscuit-kiln, in spite of the supports; and this vitreous porcelain, moreover, is always yellower, more transparent, and incapable of bearing rapid transitions of temperature, so that even the heat of boiling water frequently cracks it. It possesses some advantages as to painting, and may be made so gaudy and brilliant in its decorations, as to captivate the vulgar eye.

The best English porcelain is made from a mixture of the Cornish and Devonshire kaolin (called china-clay), ground flints, ground Cornish stone, and calcined bones in powder, or bone-ash, besides some other materials, according to the fancy of the manufacturers. A liquid pap is made with these materials, compounded in certain proportions, and diluted with water. The fluid part is then withdrawn by the absorbent action of dry stucco basins or pans. The dough, brought to a proper stiffness, and perfectly worked and kneaded on the principles detailed above, is fashioned on the lathe, by the hands of modellers, or by pressure in moulds. The pieces are then baked to the state of biscuit in a kiln, being enclosed, of course, in saggers.

This biscuit has the aspect of white sugar, and being very porous, must receive a vitreous coating. The glaze consists of ground felspar or Cornish stone. Into this, diffused in water, along with a little fire-powder and potash, the biscuit ware is dipped, as already described. The pieces are then fired in the glaze-kiln, care being taken, before putting them into their saggers, to remove the glaze-powder from their bottom parts, to prevent their adhesion to the fire-clay vessel.

Mortar Body, is a paste composed of 6 parts of clay, 3 of felspar, 2 of silex, and 1 of china-clay.

Ironstone-China. Some of the English porcelain has been called ironstone-china. This is composed usually of 60 parts of Cornish stone, 40 of china-clay, and 2 of flint-glass; or 42 of felspar, the same quantity of clay, 10 parts of flints ground, and 8 of flint-glass. Slag from iron-smelting is sometimes introduced into the paste.

The glaze for the first composition is made with 20 parts of felspar, 15 of flints, 6 of red lead, and 5 of soda, which are fritted together; with 44 parts of the frit, 22 parts of flint-glass, and 15 parts of white lead, are ground.

The glaze for the second composition is formed of 8 parts of flint-glass, 36 of felspar, 40 of white lead, and 20 of silex (ground flints).

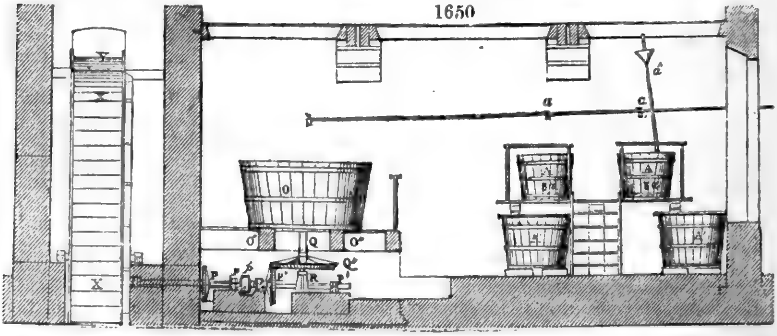
The English manufacturers employ three sorts of compositions for the porcelain biscuit: namely, two compositions not fritted; one of them for the ordinary table service; another for the dessert, service, and tea dishes; the third, which is fritted, corresponds to the paste used in France for sculpture; and with it all delicate kinds of ornaments are made.

	First composition	Second composition		Third composition	
Ground flints . . .	75	. .	66	Lynn sand	150
Calcined bones . .	180	. .	100	. .	300
China-clay . . .	40	. .	96	. .	100
Clay	70	Granite	80	Potash	107

The glaze for the first two of the preceding compositions consists of, felspar 45, flints 9, borax 21, flint-glass 20, nickel 4. After fritting that mixture, add 12 parts of red lead. For the third composition, which is the most fusible, the glaze must receive 12 parts of ground flints, instead of 9; and there should be only 15 parts of borax, instead of 21.

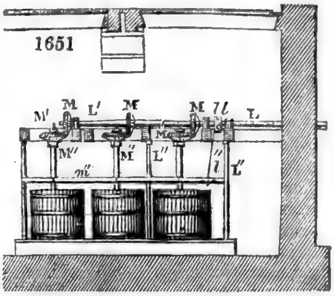
Description of the Porcelain Mill.

1. The following figures of a felspar and flint mill (*figs.* 1650, 1651) are taken from plans of apparatus constructed by Mr. Hall, of Dartford, and erected by him in the Royal Manufactory of Sèvres. There are two similar sets of apparatus, which may be employed together or in succession; composed each of an elevated tub A, and of three successive vats of reception A', and two behind it, whose top edges are upon a lower level than the bottom of the casks A, A, to allow of the liquid running out of them with a sufficient slope. A proper charge of kaolin is first put into the cask A, then water is gradually run into it by the gutter adapted to the stopcock *a*, after which the mixture is agitated powerfully in every direction by hand with the stirring-bar, which is hung within a hole in the ceiling, and has at its upper end a small tin-plate funnel to prevent dirt or rust from dropping down into the clay. The stirrer may be raised or lowered so as to touch any part of the cask. The semi-fluid mass is left to settle for a few minutes, and then the finer argillaceous pap is run off by the stopcock *a'*, placed a little above the gritty deposit, into the zinc-pipe which conveys it


1650

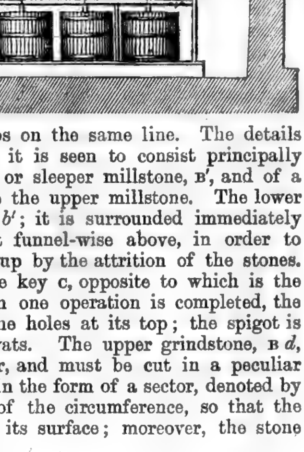
into one of the tubs A′; but as this semi-liquid matter may still contain some granular substances, it must be passed through a sieve before it is admitted into the tub. There is, therefore, at the spot upon the tub where the zinc pipe terminates, a wire-cloth sieve, of an extremely close texture, to receive the liquid paste. This sieve is shaken upon its support, in order to make it discharge the washed kaolin. After the clay has subsided, the water is drawn off from its surface by a zinc syphon. The vats A′ have covers, to protect their contents from dust. In the pottery factories of England the agitation is produced by machinery instead of the hand. A vertical shaft, with horizontal or oblique paddles, is made to revolve in the vats for this purpose.

1651

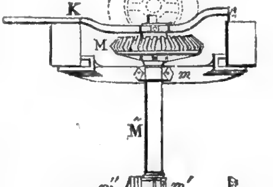


The *small triturating mill* is represented in *fig.* 1651. There are three similar grinding-tubs on the same line. The details of the construction are shown in *fig.* 1652, where it is seen to consist principally of a revolving millstone, B (*fig.* 1653), of a fast or sleeper millstone, B′, and of a vat, C, hooped with iron, with its top raised above the upper millstone. The lower block of hornstone rests upon a very firm basis, *b*′; it is surrounded immediately by the strong wooden circle *c*, which slopes out funnel-wise above, in order to throw back the earthy matters as they are pushed up by the attrition of the stones. That piece is hollowed out, partially to admit the key C, opposite to which is the faucet and spigot *c*′, for emptying the tub. When one operation is completed, the key C is lifted out by means of a peg put into the holes at its top; the spigot is then drawn, and the thin paste is run out into vats. The upper grindstone, B *d*, like the lower one, is about two feet in diameter, and must be cut in a peculiar manner. At first there is scooped out a hollowing in the form of a sector, denoted by *d e f*, *fig.* 1653; the arc *d f* is about one-sixth of the circumference, so that the vacuity of the turning grindstone is one-sixth of its surface; moreover, the stone must be channelled, in order to grind or crush the hard gritty substances. For this purpose, a wedge-shaped groove *d e g*, about an inch and a quarter deep, is made on its under face, whereby the stone, as it turns in the direction indicated by the arrow acts with this inclined plane upon all the particles in its course, crushing them and forcing them in between the stones, till they be triturated to an impalpable powder. When the grindstone wears unequally on its lower surface, it is useful to trace upon it little furrows, proceeding from the centre to the circumference, like those shown by the dotted lines *e*′ *e*″. It must, moreover, be indented with rough points by the hammer.

1652



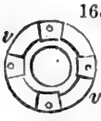
1653



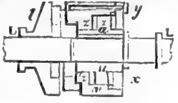
The turning hornstone-block is set in motion by the vertical shaft H, which is fixed by the clamp-iron cross, I, to the top of the stone. When the stone is new, its thickness is about 14 inches, and it is made to answer for grinding till it be reduced to about 8 inches, by lowering the clamp I upon the shaft, so that it may continue to keep its hold of the stone. The mannner in which the grindstones are turned is obvious from inspection of *fig.* 1651, where the horizontal axis L, which receives its impulsion from the great water-wheel, turns the prolonged shaft L′, or leaves it at rest, according as the clutch *l*, *l*′, is locked or open. The second shaft bears the three bevel wheels M, M, M. These work in three corresponding bevel wheels M′ M′ M′, made fast respectively to the three vertical shafts of the millstones, which pass through the cast-iron guide tubes M″M″. These are fixed in a truly vertical position by the collar-bar *m*″, *m*′, *fig.* 1652. In this figure we see at *m* how the strong cross-bar of cast iron is made fast to the wooden beams which support all the upper mechanism of the mill-work. The bearing *m′* is disposed in an analogous manner; but it is supported against two cast-iron columns, shown at L″ L″, in *fig.* 1651. The guide tubes M″ are bored smooth for a small distance from each of their extremities, and their interjacent calibre is wider, so that the vertical shafts touch only at two places. It is obvious, that whenever the shaft L′ is set agoing, it necessarily turns the wheels M and M′, and their guide tubes M″; but the vertical shaft may remain either at rest, or revolve, according to the position of the lever-click or catch K, at the top, which is made to slide upon the shaft, and can let fall a finger into a vertical groove cut in the surface of that shaft. The clamp-fork of the click is thus made to catch upon the horizontal bevel wheel M′, or to release it, according as the lever K is lowered or lifted up. Thus each millstone may be thrown out of or into gear at pleasure.

These stones make upon an average 11 or 12 turns in a minute, corresponding to 3 revolutions of the water-wheel, which moves through a space of 3 feet 4 inches in the second, its outer circumference being 66 feet. The weight of the upper stone, with its iron mountings, is about 6 cwts. when new. The charge of each mill in dry material is 2 cwts.; and the water may be estimated at from one-half to the whole of this weight; whence the total load may be reckoned to be at least 3 cwts.; the stone by displacement of the magma, loses fully 400 pounds of its weight, and weighs therefore in reality only 2 cwts. It is charged in successive portions, but it is discharged all at once. When the grinding of the siliceous or felspar matters is nearly complete, a remarkable phenomenon occurs: the substance precipitates to the bottom, and assumes in a few seconds so strong a degree of cohesion, that it is hardly possible to restore it again to the pasty or magma state; hence, if a millstone turns too slowly, or if it be accidentally stopped for a few minutes, the upper stone gets so firmly cemented to the under one, that it is difficult to separate them. It has been discovered, but without knowing why, that a little vinegar added to the water of the magma almost infallibly prevents that sudden stiffening of the deposit and stoppage of the stones. If the mills come to be set fast in this way, the shafts or gearing would be certainly broken, were not some safety provision to be made in the machinery against such accidents. Mr. Hall's contrivance to obviate the above danger is highly ingenious. The clutch *l*, *l′*, *fig.* 1651, is not a locking-crab, fixed in the common way, upon the shaft L; but it is composed, as shown in *figs.* 1654, 1655, 1656, 1657, of a hoop, *u*, fixed upon the shaft by means of a key, of a collar *v*, and of a flat ring or washer *x*, with four projections, which are fitted to the collar *v* by four bolts, *y*. *Fig.* 1655 represents the collar *v*, seen in front; that is, by the face which carries the clutch teeth; and *fig.* 1656 represents its other face, which receives the flat ring *x*, *fig.* 1657, in four notches corresponding to the four projections of the washer-ring. Since the ring *u* is fixed upon the shaft L, and necessarily turns with it, it has the two other pieces at its disposal, namely, the collar *v*, and the washer *x*, because they are always connected with it by the four bolts *y*, so as to turn with the ring *u*, when the resistance they encounter upon the shaft L′ is not too great, and to remain at rest, letting the ring *u* turn by itself, when that resistance increases to a certain pitch. To give this degree of friction, we need only interpose the leather washers *z*, *z′*, *fig.* 1654; and now, as the collar *coupling-box*, *v*, slides pretty freely upon the ring *u*, it is obvious that by tightening more or less the screw-bolts *y*, these washers will become as it were a lateral brake, to tighten more or less the bearing of the ring *u*, to which they are applied: by regulating this pressure, everything may be easily adjusted. When the resistance becomes too great, the leather washers, pressed upon one side by the collar *v*, of the washer *x*, and rubbed upon the other side by the prominence of the ring *u*, get heated to such a degree, that they are apt to become carbonised, and require replacement.

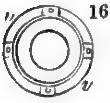
1655



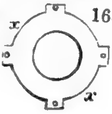
1654



1656



1657



This safety clutch may be recommended to the notice of mechanicians, as susceptible of beneficial application in a variety of circumstances.

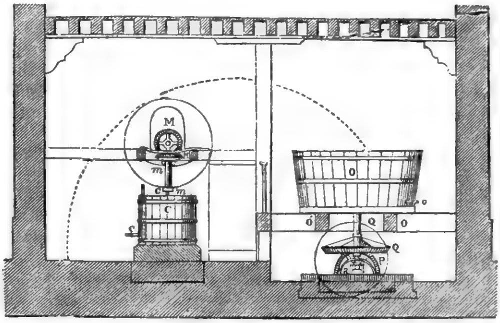
Great Porcelain Mill.—The large felspar and kaolin mill, made by Mr. Hall, for Sèvres, has a flat bed of hornstone, in one block, laid at the bottom of a great tub, hooped strongly with iron. In most of the English potteries, however, that bed consists of several flat pieces of chert or hornstone, laid level with each other. There is as usual a spigot and faucet at the side, for drawing off the liquid paste. The whole system of the mechanism is very substantial, and is supported by wooden beams.

The following is the manner of turning the upper blocks. In *fig.* 1650 the main horizontal shaft, P, bears at one of its extremities a toothed wheel, usually mounted upon the periphery of the great water-wheel (*fig.* 1658 shows this toothed wheel by a dotted line) at its other end: P carries the fixed portion *p* of a coupling-box, similar to the one just described as belonging to the little mill. On the prolongation of P, there is a second shaft, P′, which bears the moveable portion of that box, and an upright bevel wheel, P″. Lastly, in *figs.* 1650 and 1658, there is shown the vertical shaft Q, which carries at its upper end a large horizontal cast-iron wheel Q, not seen in this view, because it is sunk within the upper surface of the turning hornstone, like the clamp *d, f,* in *fig.* 1652. At the lower end of the shaft Q, there is the bevel wheel Q″, which receives motion from the wheel P″, *fig.* 1650.

The shaft, P, always revolves with the water-wheel; but transmits its motion to the shaft P′ only when the latter is thrown into gear with the coupling-box *p*′, by means of its forked lever. Then the bevel wheel P′ turns round with the shaft P′, and communicates its rotation to the bevel wheel Q″, which transmits it to the shaft Q, and to the large cast-iron wheel, which is sunk into the upper surface of the revolving hornstone.

The shaft Q is supported and centred by a simple and solid adjustment; at its lower part, it rests in a step R, which is supported upon a cast-iron arch, Q′, seen in profile in *fig.* 1650; its base is solidly fixed by four strong bolts. Four set-screws above R, *fig.* 1650, serve to set the shaft Q truly perpendicular: thus supported, and held securely at its lower end, in the step at R, *figs.* 1650 and 1658, it is embraced near the upper end by a brass bush or collar, composed of two pieces, which may be drawn closer together by means of a screw. This collar is set into the summit of a great truncated cone of cast-iron, which rises within the tub through two-thirds of the thickness of the hornstone bed; having its base firmly fixed by bolts to the bottom of the tub, and having a brass collet to secure its top. The iron cone is cased in wood. When all these pieces are well adjusted and properly screwed up, the shaft Q revolves without the least vacillation, and carries round with it the large iron wheel Q′, cast in one piece, and which consists of an outer rim, three arms or radii, and a strong central nave, made fast by a key to the top of the shaft Q, and resting upon a shoulder nicely turned to receive it.

1658



Upon each of the three arms, there are adjusted, with bolts, three upright substantial bars of oak, which descend vertically through the body of the revolving mill to within a small distance of the bedstone; and upon each of the three arcs of that wheel-ring, comprised between its three strong arms, there are adjusted, in like manner, five similar uprights, which fit into hollows cut in the periphery of the moving stone. They ought to be cut to a level at their lower part, to suit the slope of the bottom of the tub O, *figs.* 1650 and 1658, so as to glide past it pretty closely, without touching.

The speed of this large mill is eight revolutions in the minute. The turning hornstone describes a mean circumference of $141\frac{1}{3}$ inches (its diameter being 45 inches), and of course moves through about 100 feet per second. The tub, O, is 52 inches wide at bottom, 56 at the surface of the sleeper block (which is 16 inches thick), and 64 at top, inside measure. It sometimes happens that the millstone throws the pasty mixture out of the vessel, though its top is 6 inches under the lip of the tub O; an inconvenience which can be obviated only by making the pap a little thicker; that is, by allowing only from 25 to 30 per cent. of water; then its density becomes nearly equal to 2·00, while that of the millstones themselves is only 2·7; whence, supposing them to weigh only 2 cwts., there would remain an effective weight of less than ½ cwt. for pressing upon the bottom and grinding the granular particles. This weight appears to be somewhat too small to do much work in a short time; and therefore it would be better to increase the quantity of water, and put covers of some convenient form over the tubs. It is estimated that this mill will grind nearly 5 cwts. of hard kaolin or felspar gravel, in 24 hours, into a proper pap.

STONEWARE.

It is with great difficulty that any satisfactory distinction can be made between the different kinds of ware; they slide by nice degrees into one another. Stoneware of the ordinary kind, such as we see in jars, drain-pipes, and the variety of chemical utensils which are made in the Lambeth potteries, is constituted of the plastic clay, united in various proportions with some felspathic mineral, sands of different kinds, and in some cases with cement—stone or chalk; these mixtures being subjected to a heat which is sufficient to produce a partial fusion of the mass—this condition of semi-fusion being the distinguishing character of stoneware. The finer varieties of stoneware are made from well-selected clays, which, when burnt, will not have much colour. These are united with some fluxing material, by which that condition of semi-fusion is obtained which is necessary to the production of stoneware. The glaze of stoneware was always a salt glaze; it has, however, recently been the practice to glaze with a mixture of Cornish stone, flint, &c., as for earthenware.

EARTHENWARE.

This ware is exemplified in the Majolica ware, the Fayence of the French, the Dutch or Delft ware, and by the common varieties of pottery which are at present in general use in this country. All the varieties of earthenware—and they are many—consist of clay bodies, coated with an easily-fusible glaze, containing lead or borax. In Delft and Majolica ware the surface is coated with an opaque white glaze or enamel containing binoxide of tin.

Poole clay, Devonshire clay, Cornish clay, and many of the clays from the Coal-measures, and other geological formations, enter into the composition of earthenware. These are combined with certain proportions of ground flint. Porous vessels for cooling water and wine, now made extensively in many parts of this country, are similar to the ancient Spanish cooling vessels.

The Spanish *alcarazzas*, or cooling vessels, are made porous, to favour the exudation of water through them, and maintain a constantly moist evaporating surface. Lasteyrie says, that granular sea salt is an ingredient of the paste of the Spanish alcarazzas; which being expelled partly by the heat of the baking, and partly by the subsequent watery percolation, leaves the body very open. The biscuit should be charged with a considerable portion of sand, and very moderately fired.

With what has been already said in reference to the modes of manufacture, added to the remarks on printing, glazing, &c., which are to follow, the general principles which obtain in the manufacture of pottery, will, we think, be sufficiently understood.

PRINTING, PAINTING, &c.

There are two distinct methods of printing in use for china and earthenware; one is transferred on the bisque, and is the method by which the ordinary printed ware is produced, and the other is transferred on the glaze. The first is called 'press-printing,' and the latter 'bat-printing.' The engraving is executed upon copper plates, and for press-printing is cut very deep to enable it to hold a sufficiency of colour to give a firm and full transfer to the ware. The printer's shop is furnished with a brisk stove, having an iron plate on the top immediately over the fire, for the convenience of warming the colour while being worked, also a roller-press and tubs. The printer has two female assistants, called 'transferers,' and also a girl called a 'cutter.' The copper-plate is charged with colour mixed with thick boiled oil by means of a knife and 'dabber,' while held on the hot stove-plate for the purpose of keeping the colour fluid; and the engraved portion being filled, the superfluous colour is scraped off the surface of the copper by the knife, which is further cleaned by being rubbed with a boss made of leather. A thick firm oil is required to keep the different parts of the design from flowing into a mass or becoming confused while under the pressure of the rubber, in the process of transferring. A sheet of paper of the necessary size and of a peculiarly thin texture, called 'pottery tissue,' after being saturated with a thin solution of soap-and-water, is placed upon the copper-plate, and being put under the action of the press, the paper is carefully drawn off again (the engraving being placed on the stove), bringing with it the colour by which the plate was charged, constituting the pattern. This impression is given to the 'cutter,' who cuts away the superfluous paper about it; and if the pattern consists of a border and a centre the border is separated from the centre, as being more convenient to fit to the ware when divided. It is then laid by a transferer upon the ware and rubbed first with a small piece of soaped flannel to fix it, and afterwards with a rubber formed of rolled flannel. This rubber is applied to the impression very forcibly, the friction causing the colour to adhere firmly to the bisque surface, by which it is partially imbibed; it is then immersed in a tub of water, and the paper washed entirely away with a sponge, the colour, from its adhesion to the ware, and being mixed with oil, remaining unaffected. It is now necessary, prior to 'glazing,' to get rid of this oil, which is done by submitting the ware to heat in what are called 'hardening kilns,' sufficient to destroy it and leave the colour pure. This is a necessary process, as the glaze, being mixed with water, would be rejected by the print, while the oil remained in the colour.

The printing under the earthenware-glaze is generally performed by means of cobalt, and has different shades of blue according to the quantity of colouring-matter employed. After having subjected this oxide to the processes requisite for its purification, it is mixed with a certain quantity of ground flints and sulphate of baryta, proportioned to the dilution of the shade. These materials are fritted and ground; but before they are used, they must be mixed with a flux consisting of equal parts by weight of flint-glass and ground flints, which serves to fix the colour upon the biscuit, so that the immersion in the glaze-liquor may not displace the lines printed on, as also to aid in fluxing the cobalt.

The 'bat-printing' is done upon the glaze, and the engravings are for this style exceedingly fine, and no greater depth is required than for ordinary book engravings. The impression is not submitted to the heat necessary for that in the bisque, and the medium of conveying it to the ware is also much purer. The copper-plate is first charged with linseed oil, and cleaned off by hand, so that the engraved portion only retains it. A preparation of glue being run upon flat dishes about a quarter of an inch thick, is cut to the size required for the subject, and then pressed upon it, and being immediately removed, draws on its surface the oil with which the engraving was filled. The glue is then pressed upon the ware, with the oiled part next the glaze, and being again removed, the design remains; though, being in a pure oil, scarcely perceptible. Colour finely-ground is then dusted upon it with cotton wool, and a sufficiency adhering to the oil leaves the impression perfect, and ready to be fired in the enamel-kilns.

The following are the processes usually practised in Staffordshire for printing under the glaze:—

The cobalt, or whatever colour is employed, should be ground upon a porphyry slab, with a varnish prepared as follows:—A pint of linseed oil is to be boiled to the consistence of thick honey, along with 4 ounces of rosin, half a pound of tar, and half a pint of oil of amber. This is very tenacious, and can be used only when liquefied by heat; which the printer effects by spreading it upon a hot cast-iron plate.

The printing plates are made of copper, engraved with pretty deep lines in the common way. The printer, with a leathern muller, spreads upon the engraved plate, previously heated, his colour, mixed up with the above oil varnish, and removes what is superfluous with a pallet knife; then cleans the plate with a dossil filled with bran tapping, and wiping as if he were removing dust from it. This operation being finished, he takes the paper intended to receive the impression, soaks it with soap-water, and lays it moist upon the copper-plate. The soap makes the paper part more readily from the copper, and the thick ink part more readily from the biscuit. The copper-plate is now passed through the engraver's cylinder press, the proof-leaf is lifted off and handed to the women, who cut it into detached pieces, which they apply to the surface of the biscuit. The paper best fitted for this purpose is made entirely of linen rags; it is very thin, of a yellow colour, and unsized, like tissue blotting-paper.

The earthenware biscuit never receives any preparation before being imprinted, the oil of the colour being of such a nature as to fix the figures firmly. The printed paper is pressed and rubbed on with a roll of flannel, about an inch and a half in diameter, and 12 or 15 inches long, bound round with twine, like a roll of tobacco. This is used as a burnisher, one end of it being rested against the shoulder, and the other end being rubbed upon the paper; by which means it transfers all the engraved traces to the biscuit. The piece of biscuit is laid aside for a little, in order that the colour may take fast hold; it is then plunged into water, and the paper is washed away with a sponge.

When the paper is detached, the piece of ware is dipped into a caustic alkaline lye to saponify the oil, after which it is immersed in the glaze-liquor, with which the printed figures readily adhere. This process, which is easy to execute, and very economical, is much preferable to the old plan of passing the biscuit into the muffle after it had been printed, for the purpose of fixing and volatilising the oils. When the paper impression is applied to pieces of porcelain, they are heated before being dipped in the water, because, being already semi-vitrified, the paper sticks more closely to them than to the biscuit, and can be removed only by a hard brush.

The impression above the glaze is done by quite a different process, which dispenses with the use of the press. A quantity of fine clean glue is melted and poured hot upon a large flat dish, so as to form a layer about a quarter of an inch thick, and of the consistence of jelly. When cold it is divided into cakes of the size of the copper-plates it is intended to cover.

The operative (a woman) rubs the engraved copper-plate gently over with linseed oil boiled thick, immediately after which she applies the cake of glue, which she presses down with a silk dossil filled with bran. The cake licks up all the oil out of the engraved lines; it is then cautiously lifted off, and transferred to the surface of the glazed ware which it is intended to print. The glue-cake being removed, the enamel surface must be rubbed with a little cotton, whereby the metallic colours are attached only on the lines charged with oil: the piece is then heated under the muffle. The same cake of glue may serve for several impressions.

Ornaments and Colouring.—Common earthenware is coloured by means of two kinds of apparatus: the one called the blowing-pot, the other the warming-pot. The ornaments made in relief in France are made hollow (intaglio) in England, by means of a mould engraved in relief, which is passed over the article. The impression which it produces is filled with a thick clay-paste, which the workman throws on with the blowing-pot. This is a vessel like a tea-pot, having a spout, but it is hermetically sealed at top with a clay plug, after being filled with the pasty liquor. The workman by blowing in at the spout, causes the liquor to fly out through a quill pipe which goes down through the clay pipe into the liquor. The jet is made to play upon the piece while it is being turned upon the lathe; so that the hollows previously made in it by the mould or stamp are filled with a paste of a colour different from that of the body. When the piece has acquired sufficient firmness to bear working, the excess of the paste is removed by an instrument called a *tournason*, till the ornamental figure produced by the stamp be laid bare; in which case merely the colour appears at the bottom of the impression. By passing in this manner several layers of clay-liquor of different colours over each other with the blowing-pot, net-work and decorations of different colours and shades are very rapidly produced.

The serpentine or snake pots, established on the same principle, are made of tin plate in three compartments, each containing a different colour. These open at the top of the vessel in a common orifice, terminated by small quill tubes. On inclining the vessel, the three colours flow out at once in the same proportion at the one orifice, and are let fall upon the piece while it is being slowly turned upon the lathe, whereby curious serpent-like ornaments may be readily obtained. The clay-liquor ought to be in keeping with the stoneware-paste. The blues succeed best when the ornaments are made with the finer pottery mixtures given above.

White and yellow figures upon dark-coloured grounds are a good deal employed. To produce yellow impressions upon brown stoneware, ochre is ground up with a small quantity of antimony. The flux consists of flint glass and flints in equal weights. The composition for white designs is made by grinding silex up with that flux, and printing it on as for blue colours, upon brown or other coloured stoneware, which shows off the light hues.

Metallic Lustres applied to Stoneware.—The metallic lustre being applied only to the outer surface of vessels, can have no bad effect on health, whatever substances be employed for the purpose; and as the glaze intended to receive it is sufficiently fusible, from the quantity of lead it contains, there is no need of adding a flux to the metallic coating. The glaze is in this case composed of 60 parts of litharge, 36 of felspar, and 15 of flints.

The silver and platina lustres are usually laid upon a white ground, while those of gold and copper, on account of their transparency, succeed only upon a coloured ground. The dark-coloured earthenware is, however, preferable, as it shows off the colours to most advantage; and thus the shades may be varied by varying the colours of the ornamental figures applied by the blowing-pot.

The gold and platina lustre is almost always applied to a paste body made on purpose, and coated with the above-described lead-glaze. This paste is brown, and consists of 4 parts of clay, 4 parts of flints, an equal quantity of kaolin (china-clay), and 6 parts of felspar. To make brown figures in relief upon a body of white paste, a liquor is mixed up with this paste, which ought to weigh 26 ounces per pint, in order to unite well with the other paste, and not to exfoliate after it is baked.

Preparation of Gold Lustre.—Dissolve first in the cold, and then with heat, 48 grains of fine gold in 288 grains of aqua regia, composed of 1 ounce of nitric acid and 3 ounces of muriatic acid; add to that solution 4½ grains of grain tin, bit by bit; and then pour some of that compound solution into 20 grains of balsam of sulphur diluted with 10 grains of oil of turpentine. The balsam of sulphur is prepared by heating a pint of linseed oil and 2 ounces of flowers of sulphur, stirring them continually till the mixture begins to boil; it is then cooled, by setting the vessel in cold water; after which it is stirred afresh, and strained through linen. The above ingredients, after being well mixed, are to be allowed to settle for a few minutes; then the remainder of the solution of gold is to be poured in, and the whole is to be triturated till the mass has assumed such a consistence that the pestle will stand upright in it; lastly, there must be added to the mixture 30 grains of oil of turpentine, which being ground in, the gold lustre is ready to be applied. If the lustre is too light or pale, more gold must be added, and if it have not a sufficiently violet or purple tint, more tin must be used.

Platina lustre.—Of this there are two kinds: one similar to polished steel, another lighter and of a silver-white hue. To give earthenware the steel colour with platina, this metal must be dissolved in aqua regia composed of 2 parts of muriatic acid and 1 part of nitric. The solution being cooled, and poured into a capsule, there must be added to it, drop by drop, with continual stirring with a glass rod, a *spirit of tar*, composed of equal parts of tar and sulphur boiled in linseed oil and filtered. If the platina-solution be too strong, more spirit of tar must be added to it; but if too weak, it must be concentrated by boiling. Thus being brought to the proper pitch, the mixture may be spread over the piece, which being put into the muffle, will take the aspect of steel.

The preparation of platinum, by means of which the silver lustre is given to earthenware, is prepared as follows:—After having dissolved to saturation the metal in aqua regia, composed of equal parts of nitric and muriatic acid, the solution is to be poured into a quantity of boiling water. At the same time, a capsule, containing solution of sal-ammoniac, is placed upon a sand-bath, and the platinum-solution being poured into it, the metal will fall down in the form of a yellow precipitate, which is to be washed with cold water till it is perfectly edulcorated, then dried, and put up for use.

This metallic lustre is applied very smoothly by means of a flat camel's-hair brush. It is then to be passed through the muffle-kiln; but it requires a second application of the platinum to have a sufficient body of lustre. The articles sometimes come black out of the kiln, but they get their lustre by being rubbed with cotton.

Dead silver on porcelain is much more easily affected by fuliginous vapours than burnished. It may, however, by the following process, be completely protected. The silver must be dissolved in very dilute acid, and slowly precipitated; and the metallic precipitate well washed. The silver is then laid (in wavy lines?) upon the porcelain before being coloured (or if coloured, the colour must not be any preparation of gold) in a pasty state and left for 24 hours, at the expiration of which time the gold is to be laid on and the article placed in a moderate heat. The layer of gold must be very thin, and laid on with a brush over the silver before firing it; when, by the aid of a flux and a cherry-red heat, the two metals are fixed on the porcelain.

An iron lustre is obtained by dissolving a bit of steel or iron in muriatic acid, mixing the solution with the spirit of tar, and applying it to the surface of the ware.

Aventurine glaze.—Mix a certain quantity of silver-leaf with the above-described soft glaze, and grind the mixture along with some honey and boiling water, till the metal assume the appearance of fine particles of sand. The glaze being naturally of a yellowish hue, gives a golden tint to the small fragments of silver disseminated through it. Molybdena may also be applied to produce the aventurine aspect.

The granite-like gold lustre is produced by throwing lightly with a brush a few drops of oil of turpentine upon the goods already covered with the preparation for gold lustre. These cause it to separate and appear in particles resembling the surface of granite. When marbling is to be given to earthenware, the lustres of gold, platinum, and iron are used at once, which, blending in the fusion, form veins like those of marble.

Of late years a beautiful lustre has been given to porcelain by a process patented in 1857 by Messrs. Gillet and Brianchon, of Paris, and largely used at the works of Worcester and Belleek. The effect is obtained by using nitrate of bismuth as a flux to the metallic oxides which give colour, and by employing oil of lavender as a vehicle. (Spec. Patent, No. 1896, July 8, 1857.)

Pottery and ware of the Wedgwood type.—This is a kind of semi-vitrified ware, called *dry bodies*, which is not susceptible of receiving a superficial glaze. This pottery is composed in two ways: the first is with barytic earths, which act as fluxes upon the clays, and form enamels: thus the Wedgwood *jasper-ware* is made.

The white vitrifying pastes, fit for receiving all sorts of metallic colours, are composed of 47 parts of sulphate of baryta, 15 of felspar, 26 of Devonshire clay, 6 of sulphate of lime, 15 of flints, and 10 of sulphate of strontia. This composition is capable of receiving the tints of the metallic oxides and of the ochreous metallic earths. Manganese produces the dark purple colour; gold, precipitated by tin, a rose colour; antimony, orange; cobalt, different shades of blue; copper is employed for the browns and the dead-leaf greens; nickel gives, with potash, greenish colours.

One per cent. of oxide of cobalt is added; but one half, or even one quarter, of a per cent. would be sufficient to produce the fine Wedgwood blue, when the nickel and manganese constitute 3 per cent., as well as the carbonate of iron. For the blacks of this kind, some English manufacturers mix black oxide of manganese with the black oxide of iron, or with ochre. Nickel and umber afford a fine brown. Carbonate of iron, mixed with bole or *terra di Sienna*, gives a beautiful tint to the paste; as also manganese with cobalt, or cobalt with nickel. Antimony produces a very fine colour when combined with the carbonate of iron in the proportion of 2 per cent., along with the ingredients necessary to form the above-described vitrifying paste.

The following is another vitrifying paste, of a much softer nature than the preceding:—Felspar, 30 parts; sulphate of lime, 23; silex, 17; potter's clay, 15; kaolin of Cornwall (china-clay), 15; sulphate of baryta, 10.

These vitrifying pastes are very plastic, and may be worked with as much facility as English pipe-clay. The round ware is usually turned upon the lathe. It may, however, be moulded, as the oval pieces always are. The more delicate ornaments are cast in hollow moulds of baked clay, by women and children, and applied with remarkable dexterity upon the turned and moulded articles. The coloured pastes have such an affinity for each other, that the detached ornaments may be applied not only with a little gum-water upon the convex and concave forms, but they may be made to adhere without experiencing the least cracking or chinks. The coloured pastes receive only one fire, unless the inner surface is to be glazed; but a gloss is given to the outer surface. The enamel for the interior of the black Wedgwood ware is composed of 6 parts of red lead, 1 of silex, and 2 ounces of manganese, when the mixture is made in pounds' weight.

The operation called *smearing* consists in giving an external lustre to the unglazed semi-vitrified ware. The articles do not in this way receive any immersion, nor even the aid of the brush or pencil of the artist; but they require a second fire. The saggers are coated with the salt-glaze already described. These cases, or saggers, communicate by reverberation the lustre so remarkable on the surface of the English stoneware, which one might suppose to be the result of the glaze-tub, or of the brush. Occasionally also a very fusible composition is thrown upon the inner surface of the muffle, and 5 or 6 pieces called *refractories* are set in the middle of it, coated with the same composition. The intensity of the heat converts the flux into vapour; a part of this is condensed upon the surfaces of the contiguous articles, so as to give them the desired brilliancy.

Enamel-colours for painting on porcelain are metallic oxides incorporated with a fusible flux. Gold, precipitated by tin, furnishes the crimson, rose, and purple; oxides of iron and chrome produce reds; the same oxides yield black and brown, also obtained from manganese and cobalt; orange is from oxides of uranium, chromium, antimony, and iron; greens from oxides of chromium and copper; blue from oxides of cobalt and zinc. The fluxes are borax, flint, oxides of lead, &c. They are worked in essential oils and turpentine, and a very great disadvantage under which the artist labours, is that the tints upon the palette are in most cases different from those they assume when they have undergone the necessary heat, which not only brings out the true colour, but also, by partially softening the glaze and the flux, causes the colour to become fixed to the ware. This disadvantage will be immediately apparent in the case where a peculiar delicacy of tint is required, as in flesh-tones, for instance. But the difficulty does not end here, for as a definite heat can alone give to a colour a perfect hue, and as the colour is continually varying with the different stages of graduated heat, another risk is incurred; that resulting from the liability of its receiving the heat in a greater or less degree than is actually required, termed 'over-fired' and 'short-fired.' As an instance of its consequence, we cite rose-colour or crimson, which when used by the painter is a dirty violet or drab; during the process of firing it gradually varies with the increase of heat from a brown to a dull reddish hue, and from that progressively to its proper tint. But if by want of judgment or inattention of the fireman the heat is allowed to exceed that point, the beauty and brilliancy of the colour are destroyed beyond remedy, and it becomes a dull purple. On the other hand, should the fire be too slack, the colour is presented in one of its intermediate stages, as already described, but in this case extra heat will restore it. Nor must we forget to allude to casualties of cracking and breaking in the kilns by the heat being increased or withdrawn too suddenly, a risk to which the larger articles are peculiarly liable. These vicissitudes render enamel-painting in its higher branches a most unsatisfactory and disheartening study, and enhance the value of those productions which are really successful and meritorious.

In enamelling, ground-laying is the first process, in operating on all designs to which it is applied; it is extremely simple, requiring principally lightness and delicacy of hand. A coat of boiled oil adapted to the purpose being laid upon the ware with a pencil, and afterwards levelled, or as it is technically termed 'bossed,' until the surface is perfectly uniform; as the deposit of more oil on one part than another would cause a proportionate increase of colour to adhere, and consequently produce a variation of tint. This being done, the colour, which is in a state of fine powder, is dusted on the oiled surface with cotton-wool; a sufficient quantity readily attaches itself, and the superfluity is cleared off by the same medium. If it be requisite to preserve a panel ornament or any object white upon the ground, an additional process is necessary, called 'stencilling.' The stencil (generally a mixture of rose-pink, sugar, and water) is laid on in the form desired with a pencil, so as entirely to protect the surface of the ware from the oil, and the process of 'grounding,' as previously described, ensues. It is then dried in an oven to harden the oil and colour, and immersed in water, which penetrates to the stencil, and, softening the sugar, is then easily washed off, carrying with it any portion of colour or oil that may be upon it, and leaving the ware perfectly clean. It is sometimes necessary, where great depth of colour is required, to repeat these colours several times. The 'ground-layers' do generally, and should always, work with a bandage over the mouth to avoid inhaling the colour-dust, much of which is highly deleterious. 'Bossing' is the term given to the process by which the level surfaces of various colours so extensively introduced upon decorated porcelain are effected. The 'boss' is made of soft leather.

The process of gilding is as follows:—The gold (which is prepared with quicksilver and flux) when ready for use appears a black dust; it is used with turpentine and oils similar to the enamel-colours, and like them worked with the ordinary camels'-hair pencil. It flows very freely, and is equally adapted for producing broad massive bands and grounds, or the finest details of the most elaborate design.

To obviate the difficulty and expense of drawing the pattern on every piece of a service, when it is at all intricate, a 'pounce' is used, and the outline dusted through with charcoal,—a method which also secures uniformity of size and shape. Women are precluded from working at this branch of the business, though from its simplicity and lightness it would appear so well adapted for them. Firing restores the gold to its proper tint, which first assumes the character of 'dead gold:' its after brilliancy being the result of another process, termed 'burnishing.'

Glazing.—A good enamel is an essential element of fine pottery and porcelain; it should experience the same dilatation and contraction by heat and cold as the biscuit which it covers. The English enamels contain nothing prejudicial to health, as many of the foreign glazes do; no more lead being added to the former than is absolutely necessary to convert the siliceous and aluminous matters with which it is mixed into a perfectly neutral glass.

Three kinds of glazes are used in Staffordshire: one for the common pipe-clay or cream-coloured ware; another for the finer pipe-clay ware to receive impressions, called *printing body;* a third for the ware which is to be ornamented by painting with the pencil.

The glaze of the first or common ware is composed of 53 parts of white lead, 16 of Cornish stone, 36 of ground flints, and 4 of flint-glass; or of 40 of white lead, 36 of Cornish stone, 12 of flints, and 4 of flint- or crystal-glass. These compositions are not fritted; but are employed after being simply triturated with water into a thin paste.

The following is the composition of a glaze intended to cover all kinds of figures printed in metallic colours: 26 parts of white felspar are fritted with 6 parts of soda, 2 of nitre, and 1 of borax; to 20 pounds of this frit, 26 parts of felspar, 20 of white lead, 6 of ground flints, 4 of chalk, 1 of oxide of tin, and a small quantity of oxide of cobalt, to take off the brown cast, and give a faint azure tint, are added.

The following recipe may also be used:—Frit together 20 parts of flint-glass, 6 of flints, 2 of nitre, and 1 of borax; add to 12 parts of that frit, 40 parts of white lead, 36 of felspar, 8 of flints, and 6 of flint-glass; then grind the whole together into an uniform cream-consistenced paste.

As to the ware which is to be painted, it is covered with a glaze composed of 13 parts of the printing-colour frit, to which are added 50 parts of red lead, 40 of white lead, and 12 of flint; the whole having been ground together.

The above compositions produce a very hard glaze, which cannot be scratched by the knife, is not acted upon by vegetable acids, and does no injury to potable or edible articles kept in the vessels covered with it. It preserves for an indefinite time the glassy lustre, and is not subject to crack and exfoliate, like most of the Continental stoneware made from common pipe-clay.

In order that the saggers in which the articles are baked, after receiving the glaze, may not absorb some of the vitrifying matter, they are themselves coated, as above mentioned, with a glaze composed of 13 parts of common salt and 30 parts of potash, simply dissolved in water, and brushed over them.

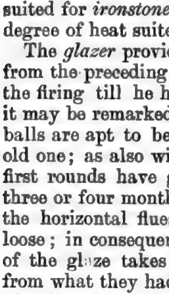
Glaze-kiln.—This is usually smaller than the biscuit-kiln, and contains no more than 40 or 45 bungs or columns, each composed of 16 or 17 saggers. Those of the first bung rest upon round tiles, and are well luted together with a finely-ground fire-clay of only moderate cohesion; those of the second bung are supported by an additional tile. The lower saggers contain the cream-coloured articles, in which the glaze is softer than that which covers the blue-printed ware; this being always placed in the intervals between the furnaces, and in the uppermost saggers of the columns. The bottom of the kiln, where the glazed ware is not baked, is occupied by printed biscuit-ware.

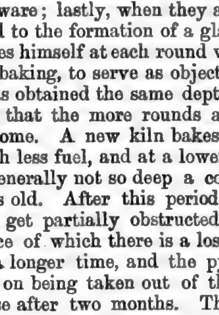
Pyrometric balls of red clay, coated with a very fusible lead-enamel, are employed in the English potteries to ascertain the temperature of the glaze-kilns. This enamel is so rich, and the clay upon which it is spread is so fine-grained and compact, that even when exposed for three hours to the briskest flame, it does not lose its lustre. The colour of the clay alone changes, whereby the workman is enabled to judge of the degree of heat within the kiln. At first the balls have a pale red appearance; but they become browner with the increase of the temperature. The balls, when of a slightly dark-red colour, indicate the degree of baking for the hard glaze of pipe-clay ware; but if they become dark brown, the glaze will be much too hard, being that suited for *ironstone*-ware; lastly, when they acquire an almost black hue, they show a degree of heat suited to the formation of a glaze upon porcelain.

The *glazer* provides himself at each round with a stock of these ball *watches*, reserved from the preceding baking, to serve as objects of comparison; and he never slackens the firing till he has obtained the same depth of shade, or even somewhat more; for it may be remarked, that the more rounds a glaze-kiln has made, the browner the balls are apt to become. A new kiln bakes a round of enamel-ware sooner than an old one; as also with less fuel, and at a lower temperature. The watch-balls of these first rounds have generally not so deep a colour as if they were tried in a furnace three or four months old. After this period, cracks begin to appear in the furnaces; the horizontal flues get partially obstructed, the joinings of the brickwork become loose; in consequence of which there is a loss of heat and waste of fuel; the baking of the glaze takes a longer time, and the pyrometric balls assume a different shade from what they had on being taken out of the new kiln, so that the first watches are of no comparable use after two months. The baking of enamel is commenced at a low temperature, and the heat is progressively increased; when it reaches the melting-point of the glaze, it must be maintained steadily, and the furnace-mouths be carefully looked after, lest the heat should be suffered to fall. The firing is continued 14 hours, and then gradually lowered by slight additions of fuel; after which the kiln is allowed from 5 to 6 hours to cool.

Muffles.—The paintings and the printed figures applied to the glaze of earthenware and porcelain are baked in muffles of a peculiar form. *Fig.* 1659 is a lateral elevation of one of these muffles; *fig.* 1660 is a front view. The same letters denote the same parts in the two figures.

a is the furnace; *b*, the oblong muffle, made of fire-clay, surmounted with a dome pierced with three apertures, *k*, *k*, *k*, for the escape of the vaporous matters of the colours and volatile oils with which they are ground up; *c* is the chimney; *d*, *d*, feedholes, by which the fuel is introduced; *e*, the fire-grate; *f*, the ash-pit; channels are left in the bottom of the furnace to facilitate the passage of the flame beneath the muffle; *g* is a lateral hole, which makes a communication across the furnace in the muffle, enabling the kiln-man to ascertain what is passing within; *k*, *k*, are the lateral chinks for observing the progress of the firing or flame; *l* is an opening scooped out in the front of the chimney to modify its draught.


1659

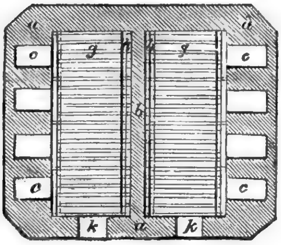

1660

The articles which are printed or painted upon the glaze are placed in the muffle without saggers, upon tripods, or moveable supports furnished with feet. The muffle being charged, its mouth is closed with a fire-tile well luted round its edges. The fuel is then kindled in the fireplaces *d*, *d*, and the door of the furnace is closed with bricks, in which a small opening is left for taking out samples, and for examining the interior of the muffle. These sample or trial-pieces, attached to a strong iron wire, show the progress of the baking operation. The front of the fireplaces is covered with a sheet-iron plate, which slides to one side, and may be shut whenever the kiln is charged.

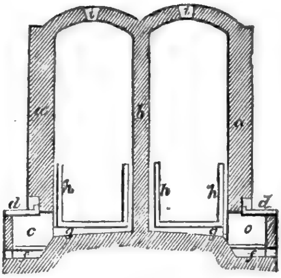
Soon after the fire is lighted, the flame, which communicates laterally from one furnace to another, envelopes the muffle on all sides, and thence rises up the chimney.

A patent was obtained by Mr. W. Ridgway for the following construction of oven, in which the flames from the fireplaces are conveyed by parallel flues, both horizontal and vertical, so as to reverberate the whole of the flame and heat upon the goods after its ascension from the flues. His oven is built square instead of round, a fire-proof partition-wall being built across the middle of it, dividing it into two chambers, which are covered in by two parallel arches. The fireplaces are built in the two sides of the oven opposite to the partition-wall: from which fireplaces narrow flues rise in the inner face of the wall, and distribute the flame in a sheet equally over the whole of its surface. The other portion of the heat is conveyed by many parallel or diverging horizontal flues, under and across the floor or hearth of the oven, to the middle or partition-wall; over the surface of which the flame which ascends from the numerous flues in immediate contact with the wall is equally distributed. This sheet of ascending flame strikes the shoulder of the arch, and is reverberated from the saggers beneath, till it meets the flame reverberated from the opposite side of the arch, and both escape at the top of the oven. The same construction is also applied to the opposite chamber. In *figs.* 1661 and 1662, *a* represents the square walls or body of the oven; *b*, the partition-wall; *c*, the fireplaces or furnaces, with their iron boilers; *d*, the mouths of the furnaces for introducing the fuel; *f*, the ash-pits; *g*, the horizontal flues under the hearth of the oven; *h*, the vertical flues; *i*, the vents in the top of the arches; and *k*, the entrances to the chambers of the ovens.

1661



1662



Before this article is concluded it is necessary that we should notice the attempts which have been made, with various degrees of success, to employ porcelain as a means for multiplying the productions of high art in a cheap form. Under the various terms of Statuary Porcelain, Parian, Carrara, &c., are produced numerous works of art, many of which are distinguished by their beauty. As the most direct method of illustrating the process of making these figures, let us suppose the object under view to be a figure or group, and this we will assume to be 2 feet high in the model. The clay, which is of the most perfect character, is mixed with flint, as in the case of manufacturing the finest stoneware china, and it is used in a semi-liquid state about the consistency of cream: this is poured into the moulds forming the various parts of the subject (sometimes as many as fifty): the shrinking that occurs before these casts can be taken out of the mould, which is caused by the absorbent nature of the plaster of which the mould is composed, is equal to a reduction of one inch and a half in the height. The moulds are made of plaster of Paris, which, when properly prepared, has the property of absorbing water so effectually that the moisture is extracted from the clay, and the ware is enabled to leave the mould, or 'deliver' with care and rapidity. Prior to use, the plaster (gypsum) is put into long troughs, having a fire running underneath them, by which means the water is drawn off, and it remains in a state of soft powder: and if its own proportion of water be again added to it, it will immediately set into a firm compact body, which is the case when it is mixed to form the mould. These casts are then put together by the 'figure-maker,' the seams (consequent upon the marks caused by the subdivisions of the moulds) are then carefully removed, and the whole worked upon to restore the cast to the same degree of finish as the original model. The work is then thoroughly dried to be in a fit state for firing, as if put in the oven while damp the sudden contraction consequent upon the great degree of heat instantaneously applied, would be very liable to cause it to crack; in the process it again suffers a further loss of one inch and a half by evaporation, and it is now but 1 foot 9 inches. Again in the 'firing' of the bisque-oven, its most severe ordeal, it is diminished 3 inches, and is then but 18 inches high, being 6 inches or one-fourth less than the original. Now, as the contraction should equally affect every portion of the details of the work, in order to realise a faithful copy, and as added to this contingency are the risks in the oven of being 'over-fired' by which it would be melted into a mass, and of being 'short-fired,' by which its surface would be imperfect, it is readily evident that a series of difficulties present themselves which require considerable practical experience successfully to meet. Indeed, the difficulties which surround the manufacture of Parian prevent its being rendered to the public at such a price as those would desire who wish to secure the introduction, amongst the people, of all examples which are calculated to refine their tastes. A biscuit-china is, by a somewhat similar process, employed in several of the porcelain-manufactories on the Continent for the production of statuettes, busks, &c., but in colour and character they are all inferior to the English Parian. See Bricks ; Clay ; Tiles.

Our *Exportations* of earthenware and chinaware have been as follow :—

1866	1867	1868	1869	1870
£1,685,864	£1,666,054	£1,682,721	£1,827,798	£1,746,153

1871	1872	1873	1874
£1,731,483	£1,936,187	£2,048,872	£1,742,653

POUDRE BARYTIQUE. See Explosive Agents.

POWDER, COLONIA. See Explosive Agents.

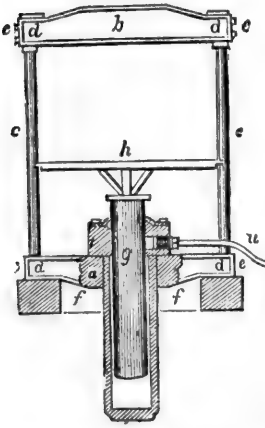
PRECIPITATE is any matter separated in minute particles from a fluid holding matter in solution, which subsides to the bottom of the vessel in a pulverulent form.

PRECIPITATE, RED. Red oxide of mercury.

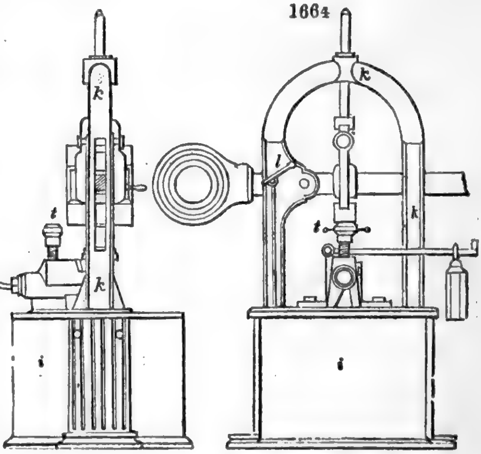
PRECIPITATE, WHITE. An ammoniacal chloride of mercury.

PRESS, HYDRAULIC. Though the explanation of the principles of this powerful machine belongs to a work upon mechanical engineering rather than to one upon manufactures, yet as it is often referred to in this work, a brief description of it cannot be unacceptable to many of our readers.

1663



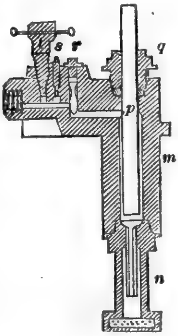
1664



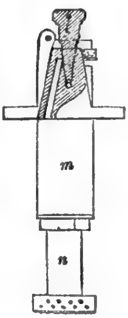
The framing consists of two stout cast-iron plates, *a*, *b*, which are strengthened by projecting ribs, not seen in the section, *fig.* 1663. The top or crown-plate *b*, and the base-plate *a*, *a*, are bound most firmly together by 4 cylinders of the best wrought iron, *c*, *c*, which pass up through holes near the ends of the said plates, and are fast wedged in them. The flat pieces *e*, *e*, are screwed to the ends of the crown and base-plates, so as to bind the columns laterally. *f*, is the hollow cylinder of the press, which, as well as the ram *g*, is made of cast iron. The upper part of the cavity of the cylinder is cast narrow, but is truly and smoothly rounded at the boring-mill, so as to fit pretty closely round a well-turned ram or piston; the under part of it is left somewhat wider in the casting. A stout cup of leather, perforated in the middle, is put upon the ram, and serves as a valve to render the neck of the cylinder perfectly water-tight by filling up the space between it and the ram; and since the mouth of the cup is turned downwards, the greater the pressure of water upwards, the more forcibly are the edges of the leather valve pressed against the insides of the cylinder, and the tighter does the joint become. This was Bramah's beautiful invention.

Upon the top of the ram, the press-plate, or table, strengthened with projecting ridges, rests, which is commonly called the 'follower,' because it follows the ram closely in its descent. This plate has a half-round hole at each of its four corners, corresponding to the shape of the four iron columns along which it glides in its up-and-down motions of compression and relaxation.

1665



1666



k, k, figs. 1663 and 1664, is the framing of a force-pump with a narrow barrel; *i* is the well for containing water to supply the pump. To spare room in the engraving, the pump is set close to the press, but it may be removed to any convenient distance, by lengthening the water-pipe *u*, which connects the discharge of the force-pump with the inside of the cylinder of the press. *Fig.* 1665 is a section of the pump and its valves. The pump *m*, is of bronze; the suction-pipe *n*, has a conical valve with a long tail; the solid piston or plunger *p*, is smaller than the barrel in which it plays, and passes at its top through a stuffing-box *q*; *r* is the pressure-valve, *s* is the safety-valve, which in *fig.* 1664 is seen to be loaded with a weighted lever; *t* is the discharge-valve, for letting the water escape from the cylinder, beneath the ram, back into the well. See the winding passages in *fig.* 1666. *u* is the tube which conveys the water from the pump into the press-cylinder. In *fig.* 1664, two centres of motion for the pump-lever are shown. By shifting the bolt into the centre nearest the pump-rod, the mechanical advantage of the workman may be doubled. Two pumps are generally mounted in one frame for one hydraulic press: the larger to give a rapid motion to the ram at the beginning, when the resistance is small; the smaller to give a slower but more powerful impulsion, when the resistance is much increased. A pressure of 500 tons may be obtained from a well-made hydraulic press with a ten-inch ram, and a two and a one inch set of pumps. See Water Pressure Machine.

PRINCE'S METAL, or Prince Rupert's metal, is a brass containing about 25 per cent. of zinc.

PRINTING. (*Imprimerie, typographie,* Fr.; *Buchdruckerkunst,* Ger.) The art of taking impressions from types and engravings in relief.

History.—The art itself is of comparatively modern origin, only 400 years having elapsed since the first book, properly so called, issued from the press; but we cannot doubt that its principle was known to the ancients. It has certainly been practised in the East from a very early period, and in a manner similar to our own first attempts. That a rude kind of printing was known to the Babylonians is evident from the undecayed bricks of that city which have been found stamped with various cuneiform and hieroglyphic characters; but as the stamp itself was in one piece or block, it was inapplicable to the propagation of knowledge, from its cost and tediousness of production.

The Chinese are the only people who have continued this primitive mode of printing to the present time. Their earliest attempts are stated in their chronicles to have been made about 50 years before the Christian era; but it was not till the reign of the Emperor Ming-tsong (927–934 A.D.) that any great advance was made in printing large numbers of comparatively cheap books. The name of the Chinese Caxton was Tong-tao. He obtained permission of the Emperor in 932 to print and circulate copies of the 'Classical Works,' as they are called, by taking impressions from stone plates, the letters cut into them, so that the impression on the paper was black and the letters themselves left white. This is still the case in all Chinese lithographic printing. Tong-tao, however, subsequently obtained the Emperor's sanction to cut in wood and print an edition of the nine 'King,' or classical books, for the use of the Imperial College in Peking. This was completed in 952; and, although intended only for the pupils of the college, it was made purchasable by any person in the empire. The process pursued in the printing of this work is precisely the same as at the present day, the following being the *modus operandi*:—

The work intended to be printed is handed to a caligraphist, who writes the separate pages on fine tracing-paper; these are given to the engraver, who glues them face downwards upon a thin plate of hard wood, called *li*, resembling that of the pear-tree, and he cuts away with a sharp instrument all those parts of the wood on which nothing is traced, leaving the transcribed characters in relief and ready for printing. The Chinese printer then, having no notion of the printing press, makes use of two fine brushes, both held in the right hand, one of which contains ink, the other dry. With the former he blackens the letters; the latter he passes gently over the paper which has been laid on them. By this means an expert workman can take a large number of impressions in one day. As the Chinese paper is thin and transparent, it is printed on one side only, two pages side by side, and the sheet has a black line down the middle, as a guide to the binder, who folds it double, and fastens the open leaves together. Various attempts have been made in the Celestial Empire to substitute moveable types for the wooden blocks, but they have always terminated in a return to the old method.

The ancient Romans made use of metal-stamps, with characters engraved in relief, to mark their articles of trade and commerce; and Cicero, in his 'De Naturâ Deorum,' has a passage from which Toland imagines the moderns have taken the hint of printing. Cicero orders the types to be made of metal, and calls them *formæ literarum*, the very words used by the first printers to express them. In Virgil's time, too, brands, with letters, were used for marking cattle, &c., with the owner's name. Landseer (*Lectures on the Art of Engraving*, 8vo. 1807) observes, 'Had the modern art of making paper been known to the ancients, we had probably never heard the names of Faust and Finiguerra; for with the same kind of stamps which the Romans used for their pottery and packages, books might also have been printed; and the same engraving which adorned the shields and pateras of the more remote ages, with the addition of paper, might have spread the rays of Greek and Etrurian intelligence over the world of antiquity. Of the truth of this assertion I have the satisfaction to lay before you the most decided proofs, by exhibiting engraved Latin inscriptions, both in cameo and intaglio, from the collection of Mr. Douce, with impressions taken from them at Mr. Savage's letter-press but yesterday [1805]. One of them is an intaglio stamp, with which a Roman oculist was used to mark his medicines; the other, which is of metal, and in cameo, is simply the proper name of the tradesman by whom it has probably been used. 'T[itus] Valagini Mauri.' *Fig.* 1667 is a facsimile of the latter stamp.

1667

TVALAGI
NIMAVRI

Books before the Invention of Printing.—The value of books and the esteem in which they were held before the invention of printing, were such, that notaries were employed to make the conveyance with as much care and attention as if estates were to be transferred. It was then thought the worthy occupation of a life either to copy or collect an amount of reading which modern improvements now present to us for a few shillings. Galen tells us that Ptolemy Philadelphus gave the Athenians 15 talents, with exemption from all tribute, and a great convoy of provisions, for the autographs and originals of the tragedies of Æschylus, Sophocles, and Euripides. 'Pisistratus is said to have been the first among the earliest of the Greeks who projected an immense collection of the works of the learned, and is supposed to have been the collector of the scattered works which passed under the name of Homer.'—*D'Israeli, Curiosities of Literature.*

Among the Romans the bulk or goodness of a man's library was the distinguishing mark of his excellence or wisdom. Middleton (*Life of Cicero*), speaking of Cicero himself, says: 'Nor was he less eager in making a collection of Greek books, and forming a library, by the same opportunity of Atticus's help. This was Atticus's own passion; who, having free access to all the Athenian libraries, was employing his slaves in copying the works of their best writers, not only for his own use, but for sale also, and the common profit both of the slave and the master.'

The passion for the enjoyment of books has in all ages led their lovers to cover them with the most costly and ornamental bindings. The ancients commonly adorned them with pendent ornaments of variously-coloured cloth, and the covers were stained with scarlet or purple colour: 'Hirsutus sparsis ut videare comis' (*Ovid*), and 'Purpureo fulgens habitu, radiantibus uncis' (*Martial*). The *unci* were rollers of wood or ivory, round which the books were rolled to prevent injury to their fronts. Ovid and Tibullus call them *cornua*, from the similarity of their ends to horns. Epistles differed from books in this: the leaves were folded together, and tied round with linen tape, and sealed with *creta Asiatica*, while books were 'bound' as above. If, however, there were more epistles than one, 'or if one epistle was to be preserved in the library, it was enclosed and turned round, and not folded: hence the word *volumen'* (*Arts of the Greeks and Romans*). 'Video quod agas: tuas quoque epistolas vis referam in volumina' (*Cicero*).

The orders respecting books in the 'Close Rolls' of the Middle Ages are interesting, not only as illustrating the literary taste of the age, but principally because they generally contain some circumstance which shows the scarcity and value of the article. It was not until a period considerably subsequent to the invention of printing that the cost and rarity of books ceased to obstruct the advancement of learning and the diffusion of knowledge.

Block Books.—Incredible difficulties were encountered by those who undertook first to lay open the stores of ancient learning, from the scarcity of MSS.; for the literary treasures of antiquity had suffered from the malice of men as well as from the hand of time. The time had now come, however, when the world's inheritance of the knowledge of Greece and Rome was to be secured from any further destruction. The art of printing books from engraved blocks of wood was no doubt invented in Holland; and, apart from the great interest created by the object for which the block books were designed, namely, the propagation of the Scriptures (being, as it were, the forerunner of the Reformation), they are extremely valuable as exhibiting the first attempts at engraving on wood in the form of books, many of them having preceded the art of printing by moveable types.—*Sotheby's 'Block Books.'*

But that prints without text, or letter-press as it is termed, were in common use at a period considerably anterior to that of the block books there is abundant evidence. It is related by Papillon, (*Traité Historique et Pratique de la Gravure en Bois*,) that the heroic actions of Alexander the Great were engraved on wood by the two Cunio, Alexander Alberic and his sister Isabella, and impressions printed from the blocks as early as 1285; and his statement has been supported by Ottley, ('Early Hist. of Engraving upon Copper and Wood, &c.,' 2 vols. 4to. 1816,) and Singer, ('Hist. of Playing Cards, &c.,' London, 4to. 1816). But Jackson, ('Hist. of Wood Engraving,') takes some trouble to prove that Papillon was excessively credulous, if not deranged. Towards the end of the fourteenth century, too, playing cards were engraved and printed for the amusement of Charles VI. King of France, who reigned from 1380 to 1421. The print of St. Christopher carrying the infant Saviour on his back across the sea, in the collection of Earl Spencer, bears an inscription and the date 1423 at the bottom of the same block; but one in the possession of Mr. J. A. G. Weigel of Leipsic is supposed to be the work of even an earlier artist.[1] These circumstances, together with the fact that the Government of Venice published a decree, dated October 11, 1441, wherein the art and mystery of making 'playing cards and coloured figures printed' are stated to have fallen into decay in consequence of the great quantity which had been made out of that state, and which were now prohibited under pain of forfeiture and fine,[2] all prove that the knowledge and practice of printing, although not applied to the spread of knowledge and the multiplication of books, had yet an existence in Europe long before the time to which it is usually attributed.

When the substructure had been completed, the work was pursued with the utmost eagerness. Great numbers of books were produced, evidently in the Chinese manner above described; for the diversity of the characters found in block books has been a never-ending puzzle to those who have endeavoured to ascertain the printer by comparison of the formation of the letters used. The workmanship of many of these picture-books was of a coarse description, without shadowing or 'cross-hatching,' tastelessly daubed over with broad colours, especially those printed for circulation amongst the poorer classes. Those best known of this class were called *Biblia Pauperum*, poor men's books, or rather books for poor preachers, and consisted of a series of rude engravings, each occupying a page, but divided into compartments containing pictorial illustrations of the most remarkable incidents mentioned in the Books of Moses, the Gospels, and the Apocalypse.

Invention of Moveable Types.—Gutenberg.—About the year 1438, while the learned Italians were eagerly deciphering their recently-discovered MSS., and slowly circulating them from hand to hand, it fell to the lot of a few obscure Germans to perfect the greatest discovery recorded in the annals of mankind. The notion of printing by moveable types, and thereby saving the endless labour of cutting new blocks of letters for every page, was reserved for John Gutenberg of Mayence. Born in that city about the beginning of the century, he settled at Strasburg about 1424, and commenced printing in the house of one Dritzehen. But having been engaged in a lawsuit connected with Dritzehen's family, and exhausted his means, he returned to Mayence, where he resumed his typographic employment in partnership with a wealthy goldsmith, named John Fust or Faust. After many experiments with his presses and moveable types, Gutenberg succeeded in printing an edition of the Vulgate, the Mayence or Mazarin Bible, so called from a copy having been discovered in the library of Cardinal Mazarin in Paris. The work was done between the years 1450 and 1455, and was printed on vellum; but there are several paper copies in England, France, and Germany. The partnership between Gutenberg and Fust having been dissolved, and the former being unable to repay part of the capital advanced by the wealthy goldsmith, the whole of the printing apparatus fell into the hands of Fust, who 'printed off a considerable number of copies of the Bible, to imitate those which were commonly sold as MSS.; and he undertook the sale of them at Paris. It was his interest to conceal this discovery, and to pass off his printed copies for MSS. But, enabled to sell his Bibles at sixty crowns, while the other scribes demanded five hundred, this raised universal astonishment; and still more when he produced copies as fast as they were wanted, and even lowered his price. The uniformity of the copies increased the wonder. Informations were given in to the magistrates against him as a magician; and in searching his lodgings a great number of copies were found. The red ink,—and Fust's red ink is peculiarly brilliant,—which embellished his copies, was said to be his blood; and it was solemnly adjudged that he was in league with the infernals. Fust at length was obliged, to save himself from a bonfire, to reveal his art to the Parliament of Paris, who discharged him from all prosecution in consideration of the wonderful invention.'—*D'Israeli, Curiosities of Literature.*

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[1] A copy of Mr. Weigel's print may be seen in Sotheby's 'Block Books,' vol. ii. p. 161.

[2] This must be regarded as the earliest authentic document respecting Printing.

This Bible was printed with large *cut* metal types; but in 1457 a magnificent edition of the 'Psalter' appeared, printed by Fust and his assistant and son-in-law, Peter Schœffer, who had been taken into partnership. In this book the new invention was announced to the world in 'a boasting colophon,' though certainly not unreasonably bold. Another edition of the 'Psalter,' one of an ecclesiastical book, Durand's account of Liturgical Offices,[1] one of the Constitutions of Pope Clement V., and one of a popular treatise on general science, called the Catholicon,[2] filled up the interval till 1462, when the second Mayence Bible proceeded from the same printers. This, in the opinion of some, is the earliest book in which *cast* metal types were employed; those of the Mazarin Bible having been cut by the hand. But this is a controverted point. In 1465 Fust and Schœffer published an edition of Cicero's 'Offices,' the first tribute of the new art to polite literature.—*Hallam, Europe during the Middle Ages,* vol. iii. p. 470.

After the lapse of a few years the pupils and workmen of Fust and Schœffer, dispersed into various countries by the sacking of Mayence, under the Archbishop Adolphus, the invention was thereby publicly made known, and the art spread over all parts of Europe. Before the year 1500, printing presses had been set up in 220 places, and a multitude of editions of the classical writers given to the world. Santander (*Dictionnaire Bibliographique choisi du quinzième Siècle,* &c., Bruxelles, 1805, 3 vols.), in his interesting and masterly work, gives at the end of his first volume a chronological table of 200 places where the art was practised during the 15th century, with the names of the printers and of the first productions of their presses. We cannot afford room for this list; but must be content to state that from Mayence the art was transplanted to Haarlem and Strasburg; from Haarlem to Rome, in 1466, by Sweynheym and Pannartz, who were the first to make use of Roman types; to Paris in 1469; to England in 1474; and to Spain in 1475; and spread so rapidly that, between the years 1469 and 1475, most towns in Germany, Italy, and the Netherlands had made successful attempts in the production of printed copies of the most valued authors of the time.

Printing in England.—Until about the period of the Restoration, William Caxton was universally acknowledged to have introduced the art of printing into this country, in or about the year 1471. But, in 1664, a Mr. Richard Atkyns, in a work called 'The Original and Growth of Printing,' &c., brought before the notice of the curious a little book, printed at Oxford, bearing the date 1468, three years before the period usually assigned to the labours of Caxton. This work took literary men by surprise, and gave rise to the most violent discussions. It is related by Atkyns that a Dutchman of the name of Frederic Corsellis was induced to desert his employers in the Low Countries, and that one Richard Turnour, an agent of King Henry VI., assisted by William Caxton, who was well known in Holland as a merchant, and therefore likely to throw the jealous possessors of the new art off their guard, brought him to England, where at Oxford he was set to work by Archbishop Bourchier, ten years before the date of Caxton's first book.[3] But the silence of Caxton on a subject in which he took the utmost interest, and in which it is stated on this occasion he was an important actor, is a strong argument against the authenticity of the story. Indeed, M. Santander (vol. i. p. 328) does not for a moment entertain the pretensions of Corsellis, and agrees with Dr. Conyers Middleton in considering that the date MCCCCLXVIII. ought to have been MCCCCLXXVIII., an X having been by accident omitted by the compositor:—'Voilà ce que Richard Atkyns imagina, et les moyens dont il se servit, en 1664, pour soutenir contre le corps des libraires de Londres, que l'imprimerie était un droit de la couronne en Angleterre. Mais le docteur Middleton, dans sa "Dissertation sur l'Origine de l'Imprimerie en Angleterre," imprimée à Cambridge, en 1734, in 4°, a prouvé démonstrativement, que l'impression d'Oxford, de "l'Expositio S. Jeronimi in Simbolum Apostolorum," est de l'an 1478, le compositeur ayant omis un X dans la date de la souscription (faute typographique dont nous avons plusieurs exemples dans les impressions du XVe siècle).' Amongst other examples of blunders of this description, the learned Doctor observes:—'But whilst I am now writing, an unexpected instance has fallen into my hands, to the support of my opinion; an "Inauguration Speech of the Woodwardian Professor, Mr. Mason," just fresh from the press, with its date given ten years earlier than it should have been, by the omission of an X, viz. MDCCXXIV.; and the very blunder exemplified in the last piece printed at Cambridge, which I suppose to have happened in the first from Oxford.'

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[1] 'Rational Divinorum Officiorum' of William Durand, 1459.

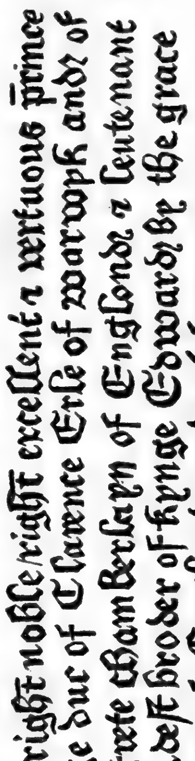
[2] 'Catholicon Januensis,' 1460, in the King's Library.

[3] The title of this volume of Corsellis is, 'Exposicio Sancti Jeronimi in Simbolum Apostolorum ad Papam Laurentiam,' and at the end, 'Explicit Exposicio, &c. Impressa Oxonis, et finita Anno Domini MCCCCLXVIII., XVII die Decembris."

Whether, however, Caxton was or not the first English printer, it is quite certain that he was the first who made use of cast metal types, the works of Corsellis having been executed with merely wooden ones. During a long residence abroad he had acquired a practical knowledge of the art; and on his return to England in 1471, set up a press at Westminster Abbey, in an old chapel[1] adjoining that edifice; and was for many years engaged in translating and printing books on a variety of subjects. His first work is 'Le Recueil des Histoires de Troyes' of Raoul le Fevre, chaplain to the Duchess of Burgundy; but 'The Dictes and Sayinges of the Philosophers' is the earliest book known to have issued from his press with the date and place of printing; and we have no proof at all that his six earlier works[2] were printed in this country. Indeed, it is stated in the Life of Caxton, in Ames's 'Typ. Antiquities,' p. xcv, that the French and English editions of the 'Histories of Troy' are justly 'admitted to have been printed abroad.'

The types used in Caxton's works, as well as in those of most of the early printers, were the Gothic or *black-letter* characters, said to have been invented by Ulphilas, first bishop of the Mœso-Goths. A facsimile of Caxton's types is here annexed, *fig.* 1668, showing the formation of his letters; and proving to our mind that, as compared with the specimens we have seen of the characters used by the Oxford printer Corsellis, they have an undoubted claim to the greater antiquity.

1668



To the right noble right excellent ⁊ vertuous prince
George duc of Clarence Erle of warwyk and of
salisburye/ grete chamberlayn of Englonde ⁊ leutenant
of Irelond oldest broder of kynge Edward by the grace
of god kynge of Englande and of france/

Caxton is said to have printed 64 books; and was followed by his pupils or assistants, Theodore Rood, John Lettou, William Machilinia, and Wynkyn de Worde, all foreigners, and Thomas Hunt, an Englishman. All these pioneers of the art worthily maintained the honour of their master's name; and Wynkyn de Worde is especially remarkable for his improvements and typographical excellence, and as having been the first printer in England who introduced the Roman letter. He printed 410 works.

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[1] From which circumstance an assemblage of printers is to this day called a 'chapel.'

[2] Viz. 1. 'Le Recueil des Histoires de Troyes;' 2. 'Propositio clarissimi oratoris Magistri Johannis Russell,' &c.; 3. 'Recuyell of the Histories of Troye'; 4. 'The Game and Playof the Chesse;' 5. The same; and 6. 'A Boke of the hoole Lyf of Jason.'

The spirit and taste of the patrons of the first printers are shown in the character of their earliest works, religious books and romances constituting the greater part of the productions of the father of English printing. But the art, although at first countenanced by the clergy, was soon looked upon with extreme jealousy by the Church. Efforts were made towards the publication of the Word of God; but for the first 60 or 70 years all copies of the Scriptures were printed in the Latin or some other language, not understood by the generality of the people. A new era had, however, arrived. The doctrines of the Reformation had proclaimed the Bible as man's best guide and teacher, and the people yearned to possess Bibles. Wickliffe's translation was never printed. The part of the Sacred Writings in the English language first produced by the printing press was the New Testament, translated by William Tindal, assisted by Miles Coverdale, afterwards Bishop of Exeter: it was printed at Antwerp, in 1526; but as it gave offence to Wolsey and the Church, the whole impression was bought up and burnt. The first complete English Bible printed by authority was Tindal's version, revised and compared with the original by Coverdale, and afterwards examined by Cranmer, who wrote a preface for it. Of this edition, hence called 'Cranmer's Bible,' 500 copies were printed by Grafton and Whitchurch, to whom Henry VIII., in letters patent, dated November 13, 1539, granted the sole right of printing the Bible for five years. It was ordered by royal proclamation to be set up in all churches throughout the kingdom, under a penalty of 40*s.* a month in every case of neglect. So great was the demand for copies of the Scriptures in the 16th century, that we have in existence 326 editions of the English Bible, or parts of the Bible, printed between 1526 and 1600.

The progress of the art in the first century of its existence was remarkable; but the earliest English printers did not attempt what the Continental ones were doing for the ancient classics. 'Down to 1540, no Greek book had appeared from an English press; Oxford had only printed a part of Cicero's Epistles; Cambridge no ancient writer whatever. Only three or four old Roman writers had been reprinted, at that period, throughout England. But a great deal was done for public instruction by the course which our early printers took; for, as one of them says: "Divers famous clerks and learned men translated and made many noble works into our English tongue, whereby there was much more plenty and abundance of English used than there was in times past." The English nobility were, probably, for more than the first half-century of English printing, the great encouragers of our press:—they required translations and abridgments of the classics, versions of French and Italian romances, old chronicles, and helps to devout exercises. Caxton and his successors abundantly supplied these wants, and the impulse to most of their exertions was given by the growing demand for literary amusement on the part of the great. Caxton, speaking of his "Boke Eneydos," says: "This present book is not for a rude uplandish man to labour therein, nor read it; but only for a clerk and a noble gentleman, that feeleth and understandeth in feats of arms, in love, and in noble chivalry." But a great change was working in Europe; the "rude uplandish man," if he gave promise of talent, was sent to school. The priests strove with the laity for the education of the people; and not only in Protestant but in Catholic countries were schools and universities everywhere founded. Here, again, was a new source of employment for the press—A, B, C's, or Absies, Primers, Catechisms, Grammars, Dictionaries, were multiplied in every direction. Books became, also, during this period, the tools of professional men. There were not many works of medicine, but a great many of law. The people, too, required instruction in the ordinances they were called upon to obey; and thus the Statutes, mostly written in French, were translated and abridged by Rastell, our first law-printer.

'After all this rush of the press of England towards the diffusion of existing knowledge, it began to assist in the production of new works, but in very different directions. Much of the poetry of the sixteenth century, which our press spread around, will last for ever: its controversial divinity has, in great part, perished. Each, however, was a natural supply, arising out of the demand of the people; as much as the chronicles, and romances, and grammars were a natural supply; and as the almanacks, and mysteries, and ballads, which the people then had, were a natural supply. Taken altogether, the activity of the press of England, during the first period of our enquiry, was very remarkable. Ames and Herbert have recorded the names of 350 printers in England and Scotland, or of foreign printers engaged in producing books for England, that flourished between 1471 and 1600. The same authors have recorded the titles of nearly 10,000 distinct works printed amongst us during the same period. Many of these works, however, were only single sheets, but on the other hand, there are, doubtless, many not here registered.' Dividing the total number of books printed during these 130 years, we find that the average number of distinct works produced each year was 75.'—*Penny Magazine.*

The first book in which Greek types occur is Cicero's 'Offices,' printed in the year 1465, in which the characters are so imperfect that the words are with difficulty deciphered; but the first work printed wholly with Greek types is a Greek Grammar, written by the learned Constantine Lascaris, printed in Milan by Dionysius Paravisinus, in 1476, in 4to. It went through several editions in Italy, France, and Switzerland. One of them, that of Aldus, printed in Venice in 1495, is the first Aldine book printed with a date. One of the most elegant specimens of ancient Greek typography, valued not only for its beauty, but also for its rarity and the accuracy of its text, is the 'Argonautica, Flor. ap Junta, 1500,' 4to. *editio princeps.*

It was not unusual for the early printers of Greek, as well as of other works, to endeavour to imitate the characters of the MSS. of the age. In this they were more or less successful. An exceedingly beautiful specimen of this kind of printing is the *editio princeps* of Isocrates: 'Orat. à Demetrio Chalcondyla, Gr. Mediol. ap. Henr. Germanus et Sebastianus ex Pontremula,' 1493, folio. The text of this edition is said to be remarkably accurate. Fabricius considers it more so than that of the Aldine edition of 1513.

The first Greek book printed in Rome was the works of Pindar: 'Pindari Opera Gr. cum Scholiis Callieggi.' Rome, 1515, 4to. This is also remarkable as the first edition with the Scholia. The first Greek work printed at Cambridge was Plato's 'Menexenus, sive Funebris Oratio, Exhortatio ad Patriam amandam atque defendam. Cantab.' Greek types were not introduced into Scotland till after the middle of the 16th century. In a 4to. volume printed in Edinburgh in 1563, entitled, 'The Confutation of the Abbote of Crosraguel's Masse,' there is an Epistle by the Printer to the Reader, apologising for his want of Greek characters, which he was obliged to supply by manuscript.

The first work printed with Roman types was Cicero's 'Epistolæ Familiares,' by Sweynheym and Pannartz, at Rome, in 1467. Italic type was invented by Aldus Manutius, about 1500.

Italy has the honour also of having printed the first Hebrew Bible, at Soncino, a small city in the Duchy of Milan, in 1488, under the superintendence of two Jewish rabbins, named Joshua and Moses. The edition of Brescia, of 1494, was used by Luther in making his German translation. But Hebrew types were not introduced into England for many years after this period; for we find that in 1524, Dr. Robert Wakefield, chaplain to Henry VIII., complains, in his 'Oratio de Laudibus,' &c., that he was obliged to omit his whole third part, as the printer (Wynkyn de Worde) had no Hebrew types. Towards the end of the 16th century, various works were printed in Syriac, Arabic, Persian, Armenian, and Coptic or modern Egyptian types; some to gratify the curiosity of the learned, and others for the liturgic uses of the Christians in the Levant.

In the 16th century the broils consequent on the Reformation, although that event stimulated religious enquiry, did much to impede the progress of the art in England. But the civil wars and the gloomy religious spirit which succeeded till the pedantry and verbal criticism of the reign of James I., and which prevailed to the Restoration, interrupted still more the production of works calculated to cultivate the understanding. Indeed, we cannot but regard this period as the least favourable to the diffusion of knowledge of any period in the history of our literature. In the British Museum is a collection of controversial and quibbling tracts amounting to the enormous number of 30,000,[1] while the impressions of new books printed during these stormy times were very few. Dr. Johnson has well remarked that the nation, from 1623 to 1664, was satisfied with two editions of Shakspeare's Plays, which, probably, together did not amount to a thousand copies. But during this period we must not forget the present Authorised Version of the Bible, translated by the forty-seven distinguished scholars appointed by James I., and printed in 1611, which is allowed by competent judges to be one of singular merit, and indeed the most perfect ever produced. An unfavourable effect was also produced on our national literature, and on the progress of the press, by the licentiousness introduced by the literary parasites and courtezans of the Restoration. Under such a state of mental depression, Milton could obtain only 15*l.* for the MS. of his immortal 'Paradise Lost,' and an Act of Parliament was actually in force enacting that only twenty printers should practise their art in the whole kingdom! Burton, who lived near this time, has drawn a miserable picture of the abject condition of literary men when they had such patrons to rely upon:—'Rhetoric only serves them to curse their bad fortunes; and many of them, for want of means, are driven to hard shifts. From grasshoppers they turn humble-bees and wasps, plain parasites, and make the Muses mules, to satisfy their hunger-starved paunches and get a meal's meat.'

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[1] Tomlinson's Collection.

In addition to these impediments, the Crown endeavoured, in the reign of Charles II., to destroy the activity of the press; 'and in this it had the example not only of all former reigns (in which nothing had been legally published without a license), but of the Long Parliament itself, which had laid severe restrictions upon the printing of "scandalous and unlicensed papers." At one time, indeed, it was ordered that no printing should be carried on anywhere but in the City of London and the two Universities; and all London printers were to enter into a bond of 300*l.* not to print anything against the Government, or without the name of the author (or at least of the licenser) on the title-page, in addition to their own.'—*Eccleston's Eng. Antiquities*, p. 325.

It has been ascertained, by counting, that the whole number of books printed during the fourteen years from 1666 to 1680, was 3,550; of which 247 were divinity, 420 law, and 153 physic, so that two-fifths of the whole were professional books; 397 were school-books, and 253 on subjects of geography and navigation, including maps. Taking the average of these fourteen years, the total number of works produced yearly was 253; but deducting the reprints, pamphlets, single sermons, and maps, we may fairly assume that the yearly average of new books was much under 100. Of the number of copies constituting an edition we have no record; we apprehend it must have been small, for the price of a book, so far as we can ascertain it, was considerable.

The period from the accession of George III. to the close of the 18th century is marked by the rapid increase of the demand for popular literature, rather than by any prominent features of originality in literary production. Periodical literature spread on every side; newspapers, magazines, reviews, were multiplied; and the old system of selling books by hawkers was extended to the rural districts and small provincial towns. Of the number-books thus produced, the quality was indifferent, with a few exceptions; and the cost of these works was considerable. The principle, however, was then first developed, of extending the market, by coming into it at regular intervals with fractions of a book, so that the humblest customer might lay by each week in a savings'-bank of knowledge. This was an important step, which has produced great effects, but which is even now capable of a much more universal application than it has ever yet received. Smollett's 'History of England' was one of the most successful number-books; it sold to the extent of 20,000 copies.

We may exhibit the rapid growth of the publication of new books, by examining the catalogues of the latter part of the eighteenth century, passing over the earlier years of the reign of George III. In the 'Modern Catalogue of Books,' from 1792 to the end of 1802, eleven years, we find that 4,096 new works were published, exclusive of reprints not altered in price, and also exclusive of pamphlets: deducting one-fifth for reprints, we have an average of 372 new books per year. This is a prodigious stride beyond the average of 93 per year of the previous period. But we are not sure that our literature was in a more healthy condition. From some cause or other, the selling price of books had increased, in most cases 50 per cent., in others, 100 per cent. The 2*s.* 6*d.* duodecimo had become 4*s.*; the 6*s.* octavo, 10*s.* 6*d.*; and the 12*s.* quarto, 1*l.* 1*s.* It would appear from this that the exclusive market was principally sought for new books; that the publishers of novelties did not rely upon the increasing number of readers; and that the periodical works constituted the principal supply of the many. The aggregate increase of the commerce in books must, however, have become enormous, when compared with the previous fifty years; and the effect was highly beneficial to the literary character. The age of patronage was gone.

According to the Census of 1861, upwards of 26,000 persons are employed in printing and 11,000 in bookbinding.

Printing in Scotland.—Printing was introduced into Scotland, and begun in Edinburgh, about 30 years after Caxton had brought it into England. Mr. Watson, in his 'History of Printing,' says that the art was introduced into Scotland from the Low Countries by the priests who fled thither from the persecutions at home. Be this as it may, we find James IV. granting a patent in 1507 to Walter Chapman, a merchant of Edinburgh, and Andrew Mollar, a workman, to establish a press in that city. According to bibliographers, the most ancient specimen of printing in Scotland extant is a collection, entitled the 'Porteus of Nobleness,' Edinburgh. In 1509, a 'Breviary of the Church of Aberdeen' was printed at Edinburgh; and a second part in the following year. Very few works, however, appear to have issued from the Scottish press for the next 30 years; but from 1541, the date from which we find James V. granting licenses to print, the art has been pursued with success in the metropolis. At present, and from the beginning of the present century, it is perhaps the most distinguished craft in the city, being conducted in all its departments of type-founding, printing, publishing, and, we may add, paper-making at the mills in the vicinity.

Ireland.—Printing was not known in Ireland till about the year 1551, when a book in black letter was issued from a press in Dublin; but till the year 1700 very little printing was executed in Ireland, and even since that period the country has acquired little celebrity in this department of the arts, although possessing some respectable printing establishments.

America.—The art of printing has readily taken root and flourished among the civilised inhabitants of North America. The first printing press established in the American colonies was one set up at Cambridge, in Massachusetts, in the year 1638, the era of the foundation of Harvard College of that place. It was only established by the exertions and joint contributions of different individuals in Europe and America; and there is no doubt that the mechanism and types were imported from England. The first work which issued from this press was the 'Freeman's Call,' and the second the 'Almanac for New England,' both in 1639; the first book printed was the New England version of the Psalms, an octavo volume of 300 pages. In 1676 books began to be printed at Boston; in 1686 printing became known in Philadelphia; and in 1693 in New York. In the year 1700 there were only four printing presses in the Colonies. Since that period, and especially since the revolution, which removed everything like a censorship of the press, the practice of the art has undergone enormous expansion. Among the occupations enumerated in the Census of 1850 were 14,740 printers and 3,414 bookbinders. In their style of typography and bookmaking the Americans are still inferior to the English, sacrificing beauty and durability to economy and despatch.—*Chambers's Information.*

France.—The activity of the French press has very greatly increased since the time of the first Napoleon. Count Daru, in 1827 (*Notions Statistiques sur la Libraire*), estimated the number of printed sheets (exclusive of newspapers) produced by the French press in 1816, at 66,852,883; and it appears that in 1836 the number of printed sheets (exclusive of newspapers) had increased to 118,857,000; so that it may now be fairly estimated at from 130,000,000 to 140,000,000 of sheets. The quality of many of the works which have issued from the French press is also very superior, such as the 'Biographie Universelle,' the 'Art de vérifier les Dates,' and 'Bayle's Dictionary;' and it is doubted whether such books could have been published in any other country.

Germany.—The German printing press is always in a state of the greatest activity; and the trade in books is very much facilitated by the book-fairs of Leipzic, the Easter fair especially being frequented by all the booksellers of Germany, besides those of France, Switzerland, Denmark, Livonia, &c., in order to settle their mutual concerns and form new connections. In 1814 began a literary deluge, which still continues to increase. For the 5,000 works which then sufficed for the annual demand, we have now from 6,000 to 8,000. Private libraries are diminishing, and the public ones are daily increasing.

In Austria the printing press has made rapid strides of late years. The Imperial Printing-office in Vienna, under the able management of M. Auer, has become an establishment of the highest interest. At the Exhibition of 1851, he presented to the notice of the public a collection of the Lord's Prayer, printed with Roman type in 608 languages and dialects, the second section of which contained 206 languages and dialects, printed in the characters proper to the language of the respective nation. He has collected together the following founts, many of which are, however, to be found in the British type-foundries:—

Hieroglyphic
Hieratic
Demotic
Ethiopic and Amharic
Himyaritic
Himyaritic (ornamented)
Cabylic, American Inscript. Touaric and Thugga
Ancient Hebrew
Samaritan
Hebrew
Raschi or Rabbinic
German Hebrew
German Raschi
Hebrew, Spanish-Levantine
Aramaic
Chaldee
Palmyric
Estrangelo
Syriac
Cufic
Arabic, Neschi
Mauritanic
Phenician
Phenician (ornamented
Punic
Numidian
Etrurian
Ancient Italian
Runic
Gothic
Celtic
Celtic (new shape)
Anglo-Saxon
Ancient Greek
Greek
Coptic
Cyrillic
Cyrillic (differently shaped)
Russian, Servian, Wallachian
Glagolitic
Albanian
Albanian (differently shaped)
Lycian
Armenian
Georgian
Georgian (ecclesiast. letters)
Persepolitan Cuneiform letters
Pehlvi
Zend
Cabool
Peguan
Oldest Indian Signs
Western Grotto Inscription
Açoka Inscription
Inscription of Guzerat
Dynasty of Gupta (Allahabad)
Bengali
Ahom
Tibetan
Passepa
Kutila (ten years after Christ)
Devanagari (Sanscrit No. 1)
Devanagari (Sanscrit No. 2)
Kashmerian
Sikh
Assam Inscription
Mahratta
Orissa
Gujeratee
Kayti-Nagari
Randscha
Bandschin-Mola
Multan
Sindhee
Nerbudda
Kistna
Telinga

Karnata
Tamul
Malayalim
Cingalese
Maldivian
Javanese
Kiousa
New Pali (No. 1)
New Pali (No. 2)
Siamese
Kambogo (with joint and without)
Laos
Birmese
Shyan
Bugis
Bisaya
Batta
Tagala
Mongolese
Mandschu
Chinese
Coreanic
Formosan
Japanese (Katakana No. 1)
Japanese (Katakana No. 2)
Japanese (Firokana)
Tschirokisian

Russia.—The art was not introduced into Russia till the year 1560, when it was made known by a Russian merchant, who conveyed thither the materials of a printing-office, with which many neat editions were printed. But as the Russians are a very superstitious nation, and apt to raise scruples without any foundation, some of them, apprehending that printing might make some confusion or change in their religion, hired men to destroy the types and presses. No attempt was made to repair this injury or to discover the perpetrators of this fact. However, since that time they have admitted the press into Moscow and St. Petersburg, where until recently it made but slow progress.

Turkey.—The total number of books printed in Constantinople during the years 1871 and 1872 were 169, of which 39 were on theology and legislation, 38 on moral literature and poetry, 28 on history and biography, 26 on various sciences, and 38 on linguistic subjects. The Turkish Imperial Printing-office showed the greatest activity in its publications, having turned out from its presses in the year 1871 alone 46,000 volumes for commercial and general purposes, and 74,000 volumes destined for the use of schools, and in 1871 50,880 of the former description and 45,000 of the latter. —*Levant Herald.*

Peculiarities of Early Printed Books.—The following are the points peculiar to the productions of the first printers :—

1. Their forms were generally either large or small folio, or at least quarto; the lesser sizes were not in use.

2. The leaves were without running title, direction word, number of pages, or divisions into paragraphs.

3. The character itself was a rude old gothic, mixed with secretary, designed on purpose to imitate the handwriting of those times; the words were printed so close to one another that it was difficult and tedious to be read, even by those who were used to manuscripts and to this method, and often led the inattentive reader into mistakes.

4. Their orthography was various and often arbitrary, disregarding method.

5. They had very frequent abbreviations, which in time grew so numerous and difficult to be understood, that it became necessary to write a book to teach the mode of reading them.

6. Their periods were distinguished by no other points than double or single ones, that is, the colon and full point; but a little after they introduced an oblique stroke, thus /, which answered the purpose of our comma.

7. They used no capital letters to begin a sentence, or for proper names of men or places.

8. They left blank spaces for titles and initial letters or other ornaments, in order to have them supplied by the illuminators, whose art, though in vogue before and after that time, did not long survive the improvements made by the printers in this branch of their art. These ornaments were exquisitely fine, and curiously variegated with the most beautiful colours, and even with gold and silver; the margins likewise were frequently charged with every variety of figures of saints, birds, beasts, monsters, flowers, &c., which had sometimes a relation to the contents of the page, though often none at all. These embellishments were costly, but for those who could not afford a great price, there were inferior ornaments, which could be done at a much cheaper rate.

9. The name of the printer, his place of residence, &c. &c., were wholly omitted, or put at the end of the book, not without some pious ejaculation or doxology.

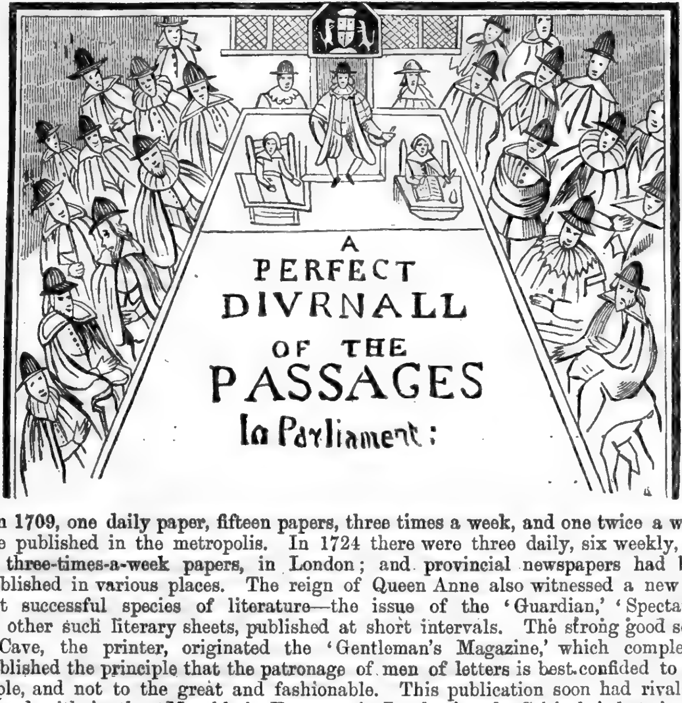
10. The date was likewise omitted or involved in some circumstantial period, or else printed either at full length, or by numerical letters, and sometimes partly one way and partly the other, thus, one thousand CCCC and lxxiii., &c., but always at the end of the book.

11. There was no variety of characters, no intermixture of Roman and Italic, these being of later invention, but their pages were continued in a Gothic letter of the same size throughout.

12. They printed but a few copies at once, for 200 or 300 was then esteemed a large impression, but upon encouragement from the learned, they increased their numbers in proportion.

Newspapers, &c.—The period of the English Revolution will be ever memorable in the literary history of this country for the establishment in great part of periodical literature. But English newspapers, properly so called, date from the first year of the Long Parliament, the oldest that has been discovered being a quarto pamphlet of a few leaves, entitled 'The Diurnal Occurences, or Daily Proceedings of both houses in this great and happy Parliament, from the 3rd November, 1640, to the 3rd of November, 1641. London: printed for William Cooke, and are to be sold at his shop at Furnival's Inn Gate, in Holborn, 1641.' (*Fig.* 1669.) More than 100 papers with different titles appear to have been published from this time to the death of the king, and upwards of 80 from that date to the Restoration. These were at first published weekly; but, as the interest increased, twice or thrice a week; and even, it would seem, daily, at least for a time. Such were the 'French Intelligences,' the 'Dutch Spy,' the 'Scots Dove,' &c.; but 'Mercuries' of all sorts were the favourite title. Thus they had 'Mercurius Acheronticus,' 'Mercurius Democritus,' 'Aulicus,' 'Britannicus,' 'Laughing Mercury,' and 'Mercurius Mastix,' which last faithfully lashed all the rest. The great newspaper editors of the day were Marchmont Needham on the Presbyterian, and Sir John Birkenhead on the Royalist side. These were followed by Sir Roger l'Estrange, who has also been ranked amongst the patriarchs of the newspaper press. Pamphlets were also issued in prodigious numbers during those troubled times; the average being calculated at four or five new ones every day.—*Eccleston's English Antiquities.*

1669



In 1709, one daily paper, fifteen papers, three times a week, and one twice a week, were published in the metropolis. In 1724 there were three daily, six weekly, and ten three-times-a-week papers, in London; and provincial newspapers had been established in various places. The reign of Queen Anne also witnessed a new and most successful species of literature—the issue of the 'Guardian,' 'Spectator,' and other such literary sheets, published at short intervals. The strong good sense of Cave, the printer, originated the 'Gentleman's Magazine,' which completely established the principle that the patronage of men of letters is best confided to the people, and not to the great and fashionable. This publication soon had rivals to contend with in the 'Monthly,' 'European,' 'London,' and 'Critical;' but it has survived them all; and a complete set of 'The Gentleman' is highly prized at the present day, and is extremely amusing and valuable.

The first newspaper published in Scotland was the 'Caledonian Mercury,' in 1660, under the title of 'Mercurius Caledonius;' but its publication was soon after interrupted. In 1750 a newspaper was, for the first time, attempted in Glasgow.

The increase of newspapers in America has been much more rapid than in this country; in consequence partly, no doubt, of the greater increase of population in the Union, but more probably of their freedom from taxation, and of the violence of party contests. According to a return published some few years back, the aggregate circulation of papers and other publications was about 5,000,000; and the entire number of copies printed annually in the United States amounted to about 422,600,000 annually.

The first newspaper published in the West Indies is said to have been the 'Barbadoes Mercury.' It was established in 1733, and died in 1852.

Practice of Printing.—The workmen principally employed in printing are of two kinds: *compositors*, who *set up* the types into lines and pages according to the MS. or *copy* furnished by the author; and *pressmen*, who apply ink to the surface of the *form* of types, and take off the impressions upon paper.

Composition.—The mode of proceeding described hereafter is that which is pursued in most of the extensive establishments in London:—The first thing to be done, when the sizes of page, type, and paper, are determined on, is to look over the MS., and see that it is correctly paged. It is then handed to a *clicker*, or foreman of a *companionship*, or certain number of compositors, each of whom has a *taking of copy*, or convenient portion of MS., given to him, to be set up in type.

Types.—Although most of the early printers were type-founders themselves, it does not appear in any prologue or colophon to the books printed by Caxton that he lays claim to the title of type-founder. It would appear that he obtained his type, which is precisely of the same character as that of John Brito of Bruges, from that city, or from the same founders who supplied or manufactured it for John Valdener of Utrecht. But as the art extended the workmanship became inferior; 'so that while the productions of the first printers were executed in a very superior style, and the embellishments showed a great proficiency both in design and engraving, the productions of their competitors had all the crudeness and imperfection of a new invention; and in the 17th century it had retrograded to a very low state. At the commencement of the 18th century, Caslon made great improvements in types; as also, Baskerville of Birmingham, in 1750, both in types and printing: which were subsequently carried on by Besley, Bulmer, Clowes, Corrall, Davison, McCreery, Spottiswoode, Whittingham, and a few others in London; by the Foulis, in Glasgow; the Ballantynes, in Edinburgh; by Bodoni at Parma; by Didot in Paris;' and by Brockhaus in Leipzic.

Printers' types (from τύπος, *tupos*, literally *a blow*, hence the mark left by a blow,) are of great variety in size, amounting to forty or fifty: the smallest is called *Brilliant*, but is seldom used; *Diamond* is a size larger, and *Pearl* larger still, which latter type is used for printing the smallest Bibles and Prayer-books.

The following is a view of the comparative sizes used in printing books:—

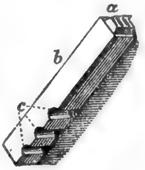
Diamond . . .	To the art of printing it is acknowledged we owe the Reformation. It has been justly remarked that
Pearl	To the art of printing it is acknowledged we owe the Reformation. It has been justly
Ruby	To the art of printing it is acknowledged we owe the Reformation. It has been
Nonpareil . .	To the art of printing it is acknowledged we owe the Reformation. It has
Minion . . .	To the art of printing it is acknowledged we owe the Reformation.
Brevier . . .	To the art of printing it is acknowledged we owe the Reformatio
Bourgeois . .	To the art of printing it is acknowledged we owe the Refor
Long Primer . .	To the art of printing it is acknowledged we owe the R
Small Pica . .	To the art of printing it is acknowledged we owe
Pica	To the art of printing it is acknowledged we
English . . .	To the art of printing it is acknowled
Great Primer .	To the art of printing it is ack

The larger sizes, used for printing bills posted in the streets, or broadsides, are usually called *Double Pica*, *Two-line Pica*, *Two-line English*, *Five-line Pica*, *Ten-line Pica*, and so on. A complete assortment of printing types of one size is called a *fount*, and the fount may be regulated to any weight. Type-founders have a scale, or *bill*, as it is called, of the proportional quantity of each letter required for a fount. The letter *e*, as will be seen from the *bill* on the following page, is used more, and the letter *z* less, frequently than others.

In setting up indexes and similar matter, the capitals mentioned would be considerably deficient. This would also be the case with French and Italian works, where accented letters are used in great numbers.

The type itself is a thin metallic bar, an inch in length (see *fig.* 1670), which represents the letter *m*: *a* is the face, *b* the *body*, and *c* the *nicks* or notches. Whatever size of type is used, each letter must be perfectly true in its angles, otherwise the form could never be *locked up*. Besides letters, there are types for commas, periods, quotation-marks, semicolons, and all other characters used in printing.

1670



Type-metal is an alloy of lead and antimony, the usual proportions being one part of antimony to three of lead; but a superior and harder kind is sometimes made by alloying two parts of lead with one of antimony and one of tin. Both of these alloys take a sharp impression from the mould or matrix, owing to their expansion on solidification, and they are hard enough to stand the work of the press, without being brittle or liable to fracture. Roman and Italic types are the letters most commonly used in printing books in Europe and America, and these have undergone every change in form that fancy or taste could suggest: *fat-faced*, or those which print black; *skeleton*, or those which print with a fine, uniform line; *antique*, or those with an almost uniform thickness, but strong and heavy; *clarendon*, a modification of antique; *expanded*, or letters widened horizontally; *Elzevir* and *compressed*, or tall thin letters; *Baskerville*, a good, round, bold face; *Italic*, inclining to the left, as well as to the right; and all the varieties of *church-text*, *German-text*, *Gothic*, and *Elizabethan*; *old cut* and *old style*; *script*, &c. The scale of sizes given on p. 642, from Savage, shows the variations in the depth of the type cast by the different founders.

BILL OF PICA.—WEIGHT 800 POUNDS.—ITALIC $\frac{1}{10}$TH.

a	8,500	è	100	0	1,300	K	150
b	1,600	ì	100	£	—	L	250
c	3,000	ò	100	A	600	M	200
d	4,400	ù	100	B	400	N	200
e	12,000	â	200	C	500	O	200
f	2,500	ê	200	D	500	P	200
g	1,700	î	100	E	600	Q	90
h	6,400	ô	100	F	400	R	200
i	8,000	û	100	G	400	S	250
j	400	ä	100	H	400	T	326
k	800	ë	100	I	800	U	150
l	4,000	ï	100	J	300	V	150
m	3,000	ö	100	K	300	W	200
n	8,000	ü	100	L	500	X	90
o	8,000	ç	100	M	400	Y	150
p	1,700	,	4,500	N	400	Z	40
q	300	;	800	O	400	Æ	20
r	6,200	:	600	P	400	Œ	15
s	8,000	.	2,000	Q	180		
t	9,000	-	1,000	R	400	Spaces	
u	3,400	?	200	S	500	Thick	18,000
v	1,200	!	150	T	650	Middle	12,000
w	2,000	’	700	U	300	Thin	8,000
x	400	†	100	V	300	Hair	3,000
y	2,000	‡	100	W	400	m quad.	2,500
z	200	*	100	X	180	n quad.	5,000
&	200	]	150	Y	300		
fi	500	‖	100	Z	80	Large quad.	
ff	400	§	100	Æ	40		
fl	200	)	300	Œ	30		
ffl	100	¶	60	A	300	2 em	about 80 lbs.
ffi	150	1	1,300	B	200	3 em	
æ	100	2	1,200	C	250	4 em	
œ	60	3	1,100	D	250		
á	100	4	1,000	E	300	Metal rules	
é	250	5	1,000	F	200		
í	100	6	1,000	G	200	1 em	—
ó	100	7	1,000	H	200	2 em	—
ú	100	8	1,000	I	400	3 em	—
à	200	9	1,000	J	150		

In Moxon's time, in 1683, it will be seen that there were only ten types with specific names, whereas, we have now twenty-one.

The materials from which types and stereotype-plates are cast are technically called *metal*, and consist of certain proportions of lead, tin, and antimony, melted together. Until recently, types were always cast in little moulds held in the hands, the melted metal being poured in from a small ladle; but now they are thrown off with great rapidity by machinery. The type-casting machine consists of a mould, constructed so as, by means of a crank, to open for the purpose of letting the type drop out, and then to shut together again very closely and exactly; the opening and shutting being performed every time the crank is turned once round. Each time the crank revolves, and is brought up to the furnace-mouth (a small orifice not much larger than a pin-hole), and takes a supply of metal. This metal is driven by a force-pump in a reservoir, worked by the crank, into the mould, and the type is formed. The types are then rubbed smooth upon stones; *set up*, or arranged in rows, for inspection by the *dresser*, who carefully examines them, and rejects those which are bad, giving the perfect ones the finishing touch. The most complete process is, perhaps, that of Messrs. Johnson and Atkinson. A double line of grooves is placed side by side. At one end is a reservoir of molten lead, to which the mould is brought; a jet of metal is thrown into the mould, which then opens, and deposits the type on a travelling apparatus in the groove. As the groove fills, it is impelled along, and in its progress, the shanks are taken off. At the end, the position of the type is reversed by the machinery into the returning groove, in which it is rubbed, dressed, has the bottoms planed, and the nicks cut. On arriving at the exit end of the groove, it is received into a type-founder's stick, which has to be removed as it is filled, and the type is then ready for packing. The great advantage in type-machines consists in the increased facility of production. One machine and one man in ten hours will produce 30,000 brevier types (or 60 lbs.), the size used for this work, while by hand-labour only 5,000 (or 10 lbs.,) could be cast in the same time.

Messrs. Miller and Richards, of Edinburgh and London, employ not less than eighty steam type-casting machines, equalling in production the labour of 480 men.

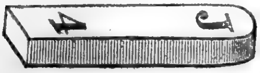
Number of Lines of the different-sized Types contained in One Foot.

	Moxon, 1683	Caslon, 1841	V. and J. Figgins, 1841	Thorowgood and Besley, 1841	Alexander Wilson and Sons, 1841
Diamond . . .	...	204	205	210	204
Pearl . . .	184	178	180	184	178
Ruby . . .	...	166	165	163	166
Nonpareil. . .	150	144	144	144	144
Emerald . . .	...	...	128	...	128
Minion . . .	...	122	122	122	122
Brevier . . .	112	111	107	112	111
Bourgeois. . .	...	102	101½	103	102
Long Primer . .	92	89	90	92	89
Small Pica . .	...	83	82	82	83
Pica. . . .	75	72	72½	72	72
English . . .	66	64	64	64½	64
Great Primer . .	50	51	51	52	51
Paragon . . .	...	44½	44½	...	44½
Double Pica . .	38	41½	41½	41	41½
Two-line Pica . .	...	36	36	36	36
Two-line English .	32	32	32	32¼	32
Two-line Great Primer	...	25½	25½	26	25½
Two-line Double Pica	...	20¾	20¾	20½	20¾
Trafalgar. . .	...	20	20	...	20
Canon . . .	17½	18	18	18	18

The beauty of type depends upon the delicacy with which the *matrix*, or mother-type, is formed. This mould is a short thick bar of copper, with the form of the letter intended to be produced stamped on one side of it (*fig.* 1671). The letter of the matrix is stamped in by means of a punch, a small piece of steel, a letter cut upon one end, and the other end a flat head to receive the blow of a hammer (*fig.* 1672).

The length of the body of a type is called its *height to paper*; and this, unfortunately, is not uniform, there being a London and a Scotch height, the former not so high as the latter.

1671



1672

In the last century, a fount of type weighing 500 lbs. was considered a good weight; but now, so much has printing increased, it is not an uncommon thing in the principal houses in London to keep a fount of 20,000 or 30,000 lbs. in common use. The following are the names of the types in English, Dutch, French, German, and Italian; but some of the German names vary in different parts of Germany :—

1. Diamond, the smallest.
2. Pearl. (*Fr.* La Parisienne or Sédanoise ; *Ger.* Perle ; *Ital.* Occhio di Mosca.)
3. Ruby.
4. Nonpareil. (*Dutch,* Nonpareil ; *Fr.* La Nonpareille ; *Ger.* Nonpareille ; *Ital.* Nompariglia.)
5. Emerald.
6. Minion. (*Fr.* La Mignonne ; *Ger.* Colonel ; *Ital.* Mignona.)
7. Brevier. (*Dutch,* Brevier ; *Fr.* Le Petit Texte ; *Ger.* Petit, or Jungfer ; *Ital.* Piccolo Testo.)
8. Bourgeois. (*Dutch,* Bourgeois ; *Fr.* La Gaillarde ; *Ger.* Bourgeois ; *Ital.* Gagliarda.)
9. Long Primer. (*Dutch,* Garmond ; *Fr.* Le Petit Romain ; *Ger.* Corpus, or Garmond ; *Ital.* Garamone.)
10. Small Pica. (*Dutch,* Dessendiaan ; *Fr.* La Philosophie ; *Ger.* Brevier, or Rheinländer ; *Ital.* Filosofia.)
11. Pica. (*Dutch,* Mediaan ; *Fr.* Le Cicéro ; *Ger.* Cicero ; *Ital.* Lettura.)
12. English. (*Dutch,* Augustyn ; *Fr.* Le Saint-Augustin ; *Ger.* Mittel ; *Ital.* Silvio.)
13. Great Primer. (*Dutch,* Text ; *Fr.* Le Gros Romain ; *Ger.* Tertia ; *Ital.* Testo.)
14. Paragon. (*Dutch,* Paragon ; *Fr.* Le Petit Parangon ; *Ger.* Paragon ; *Ital.* Paragone.)
15. Double Pica. (*Dutch,* Dubbelde Dessendiaan ; *Fr.* Le Gros Parangon ; *Ger.* Text, or Secunda ; *Ital.* Due Linee Filosofia.)
16. Two-line Pica. (*Dutch,* Dubbelde Mediaan ; *Fr.* Les Deux Points de Cicéro, La Palestine ; *Ger.* Doppelcicero.)
17. Two-line English. (*Dutch,* Dubbelde Augustyn ; *Fr.* Le Petit Canon ; *Ger.* Doppelmittel ; *Ital.* Canoncino.)
18. Two-line Great Primer. (*Dutch,* Kanon ; *Fr.* Les Deux Points de Gros Romain ; *Ger.* Kleine Canon ; *Ital.* Grosso Testo.)
19. Two-line Double Pica. (*Dutch,* Groote Kanon ; *Fr.* Le Trismégiste ; *Ger.* Grobe Canon.)
20. Trafalgar.
21. Canon. (*Dutch,* Parys Romeyn ; *Fr.* Le Gros Canon ; *Ger.* Kleine Missal ; *Ital.* Canone.)

In 1457 cast types were invented by Peter Schoeffer ; in 1800, the lever, or American mould, was introduced ; in 1823, Henri Didot's polymatype, still successfully used in France, was worked in London by Pouchée, but failed through the opposition of the associated type-founders ; in 1853, Mr. Johnson patented his machine for casting type mechanically without variation of body ; and in the year following, he perfected his process for making hard metal type by substituting tin for lead, entirely or partially, in the ordinary compounds.

The types are arranged, each sort by itself, in two *cases,*—an upper and a lower,—in little cells or *boxes.* The upper case, having ninety-eight boxes, contains the capital and small capital letters, figures, accents, and other types not used so frequently as the smaller letters ; and in the lower case, having fifty-four boxes, are disposed the small letters, together with the points, spaces, quadrats, &c. The boxes in the cases are arranged in the best possible manner for facilitating the work of the compositor, and enabling him to pick up the types rapidly,—the letters most frequently used being placed nearest to his hand.

In *setting up,* or *composing,* the compositor stands opposite to his cases ; and, having received directions respecting the size of the type, the width of the page, the author's wishes as to punctuation, capitals, italics, &c., places his copy or MS. before him, on a spare part of the upper case, and holds in his left hand a small instrument called a *composing stick,* usually made of iron, with a moveable slide, capable, by means of a screw, of being adjusted to the different widths required in miscellaneous printing, as

Pair of Cases according to the Modern Method.

Upper.

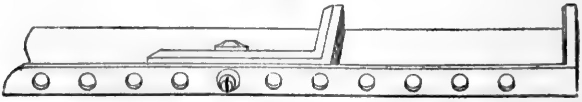
A	B	C	D	E	F	G	A	B	C	D	E	F	G
H	I	K	L	M	N	O	H	I	K	L	M	N	O
P	Q	R	S	T	V	W	P	Q	R	S	T	V	W
X	Y	Z	Æ	Œ	J	U	X	Y	Z	Æ	Œ	J	U
ä	ë	ï	ö	ü			â	ê	î	ô	û	§	‡
1	2	3	4	5	6	7	à	è	ì	ò	ù	‖	†
8	9	0	£	ç	H.S.	k	á	é	í	ó	ú	¶	*

Lower.

<table>
<tr><td>&</td><td>[</td><td>æ</td><td>œ</td><td>'</td><td>j</td><td rowspan="3">e</td><td>*Thin Sp.*</td><td>(</td><td>?</td><td>!</td><td>;</td><td></td><td>fl</td></tr>
<tr><td></td><td rowspan="2">b</td><td colspan="2" rowspan="2">c</td><td colspan="2" rowspan="2">d</td><td rowspan="2">i</td><td colspan="2" rowspan="2">s</td><td rowspan="2">f</td><td rowspan="2">g</td><td></td><td>ff</td></tr>
<tr><td></td><td></td><td>fi</td></tr>
<tr><td>ffi</td><td rowspan="2">l</td><td colspan="2" rowspan="2">m</td><td colspan="2" rowspan="2">n</td><td rowspan="2">h</td><td rowspan="2">o</td><td rowspan="2">y</td><td rowspan="2">p</td><td rowspan="2">,</td><td rowspan="2">w</td><td rowspan="2">*en*</td><td rowspan="2">*em*</td></tr>
<tr><td>ffl</td></tr>
<tr><td>z</td><td rowspan="2">v</td><td colspan="2" rowspan="2">u</td><td colspan="2" rowspan="2">t</td><td rowspan="2">*Spaces.*</td><td rowspan="2">a</td><td colspan="2" rowspan="2">r</td><td>q</td><td>:</td><td colspan="2" rowspan="2">*Quadr.*</td></tr>
<tr><td>x</td><td>.</td><td>-</td></tr>
</table>

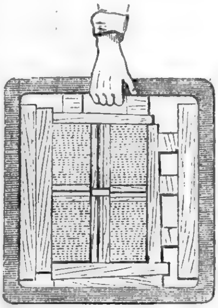
seen in the illustration (*fig.* 1673). With the right hand he picks up the types, and arranges them one by one in his composing stick. He does not look at the face, but only glances at the nick (*fig.* 1670, *c*), and takes it for granted that if it come from the right box it must be the right letter. He secures each letter with the thumb of the left hand, as the types are placed side by side in line from left to right; and, when he comes to the end of his line, and finds that he has a syllable or word which will not fill out the measure, he has to perform a task which requires considerable care and taste. This is called *justification*. The first and last letters must be at the extremities of the line; and there must not be wide spaces between some words and crowding in others, but the distances between them must be made as nearly as possible uniform by changing the *spaces* (or short blank types, not so high as the letters, and therefore giving no impression), and thus *getting in* or *driving out* part or the whole of a word. The first line being thus justified, the compositor proceeds

1673



with the setting-up of the next, and so on with a sufficient number of lines to fill his stick, and then lifts the *handful*, or mass of types, out of the stick, and places them upon a *galley*, or oblong tray of wood or metal, having an edge to the left side and top half an inch in height. This operation of filling and emptying the stick is repeated till the galley is sufficiently full, or the taking of copy is finished; when the *matter*, as it is then called, is taken away by the clicker, who divides it into the required lengths of pages, placing head-lines, signatures, &c., and binding them round tightly with cord. The clicker then *lays down* the pages in their proper positions on the *imposing stone*,—a flat, smooth slab of stone, or, better, of iron. The *chase*, a frame of iron, divided into compartments like the sashes of a window, is put round the pages, and the form *dressed* thus: a set of *furniture*, consisting of slips of wood or metal, about half an inch in height, and of various thicknesses, is placed, some at the head, called *head-sticks*, some between the pages, called *gutters*, and others at the sides and feet, called *side-* and *foot-sticks*. The side- and foot-sticks are larger at one end than at the other, so that small wedges of wood, or *quoins*, may be driven tightly between them and the sides of the chase, locking up the types so firmly, that the *form*, as the mass is called (*fig.* 1674), may be carried from place to place with perfect safety. A form of eight pages of this Dictionary contains between 40,000 and 50,000 separate letters and spaces.

1674

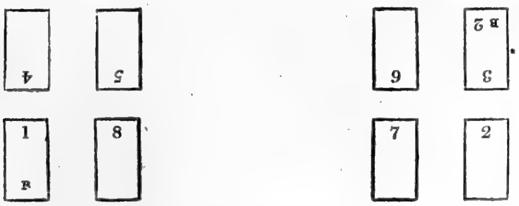


The sizes of books are reckoned by the number of leaves into which a sheet of paper is folded. Thus the largest size is *broadside*, or the whole size of the sheet; *folio*, or half the sheet; *quarto*, or a sheet folded into four leaves; *octavo*, or the sheet folded into eight leaves; *duodecimo*, or the sheet folded into twelve leaves; and so on. In imposing, the pages are of course laid down in positions the reverse of those they will take when printed. The following Tables show the mode of imposing some of the most common sizes.

When the process of imposing is completed, the form is carried to a press, and an impression is taken, called the *first proof*. This proof, with the MS., is handed to the corrector of the press, or *reader*, and a *reading boy* reads the copy to him while he examines the proof and marks the necessary corrections and errors of the compositor. In correcting a proof-sheet a set of symbols are used for the purpose of calling the attention of the compositor to the several kinds of errors, and to direct him how they

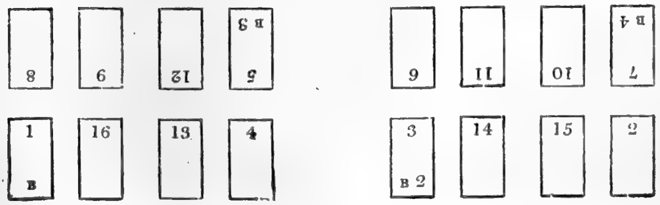
Sheet of Quarto.

Outer Form. *Inner Form.*

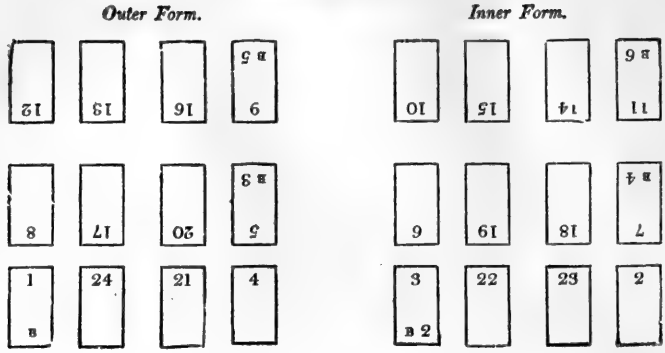


Sheet of Octavo.

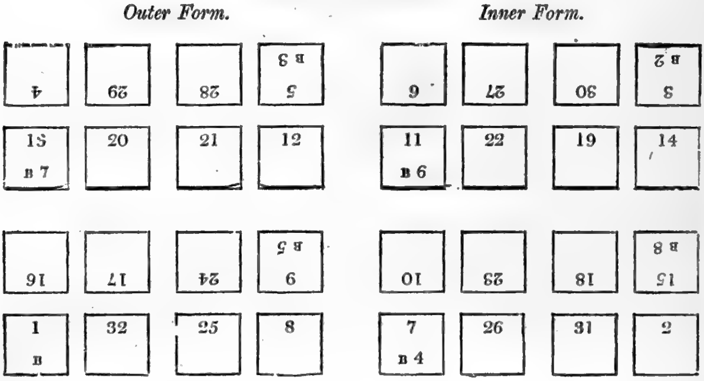
Outer Form. *Inner Form.*



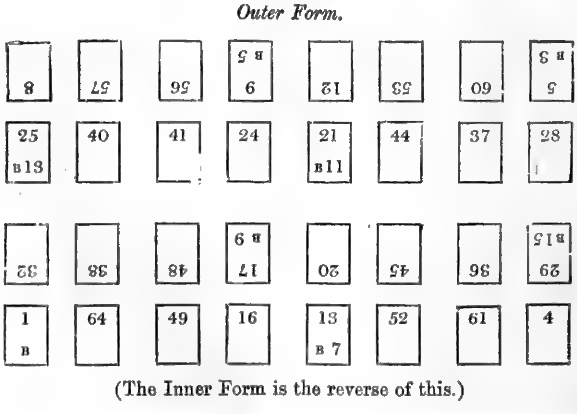
SHEET OF TWELVES.


Outer Form. *Inner Form.*
12
13
16
9 B 5
10
15
14
11 B 6
8
17
20
5 B 3
6
19
18
7 B 4
1 B
24
21
4
3 B 2
22
23
2

SHEET OF SIXTEENS.


Outer Form. *Inner Form.*
4
29
28
5 B 3
6
27
30
3 B 2
13 B 7
20
21
12
11 B 6
22
19
14
16
17
24
9 B 5
10
23
18
15 B 8
1 B
32
25
8
7 B 4
26
31
2

SHEET OF THIRTY-TWOS.


Outer Form.
8
57
56
9 B 5
12
53
60
5 B 3
25 B 13
40
41
24
21 B 11
44
37
28
32
33
48
17 B 9
20
45
36
29 B 15
1 B
64
49
16
13 B 7
52
61
4

(The Inner Form is the reverse of this.)

are to be amended. These marks are best shown by the following specimen of a corrected proof from Brande's 'Dictionary,' the explanation of each mark being given in the left-hand column :—

1. Where a word is to be changed from small letters to capitals, draw three lines under it, and write *caps.* in the margin.

2. Where there is a wrong letter, draw the pen through that letter, and make the right one opposite in the margin.

3. A letter turned upside down.

4. The substitution of a comma for another point, or for a letter put in by mistake.

5. The insertion of a hyphen.

6. To draw the letters of a word close together.

7. To take away a superfluous letter or word the pen is struck through it, and a round top *d* made opposite, being the contraction of *deleatur*, to expunge.

8. Where a word has to be changed to Italic draw a line under it, and write *Ital.* in the margin; and where a word has to be changed from Italic to Roman, write *Rom.* opposite.

9. When words are to be transposed three ways of marking them are shown; but they are not usually numbered except more than three words have their order changed.

10. The transposition of letters in a word.

11. To change one word for another.

12. The substitution of a period or a colon for any other point. It is customary to encircle these two points with a line.

13. The substitution of a capital for a small letter.

14. The insertion of a word, or a letter.

15. When a paragraph commences where it is not intended, connect the matter by a line, and write in the margin opposite *run on.*

16. Where a space or a quadrat stands up and appears, draw a line under it, and make a strong perpendicular line in the margin.

17. When a letter of a different size from that used, or of a different face, appears in a word, draw a line either through it or under it, and write opposite *wf.*, for 'wrong fount.'

18. The marks for a paragraph, when its commencement has been omitted.

19. When one or more words have been struck out, and it is subsequently decided that they shall remain, make dots under them, and write the word *stet* in the margin.

20. The mark for a space where it has been omitted between two words.

21. To change a word from small letters to small capitals make two lines under the word, and write *sm. caps.* opposite. To change a word from small capitals to small letters make one line under the word, and write in the margin *lo. ca.* for 'lower case.'

22. The mark for the apostrophe; and also the marks for turned commas, which designate extracts.

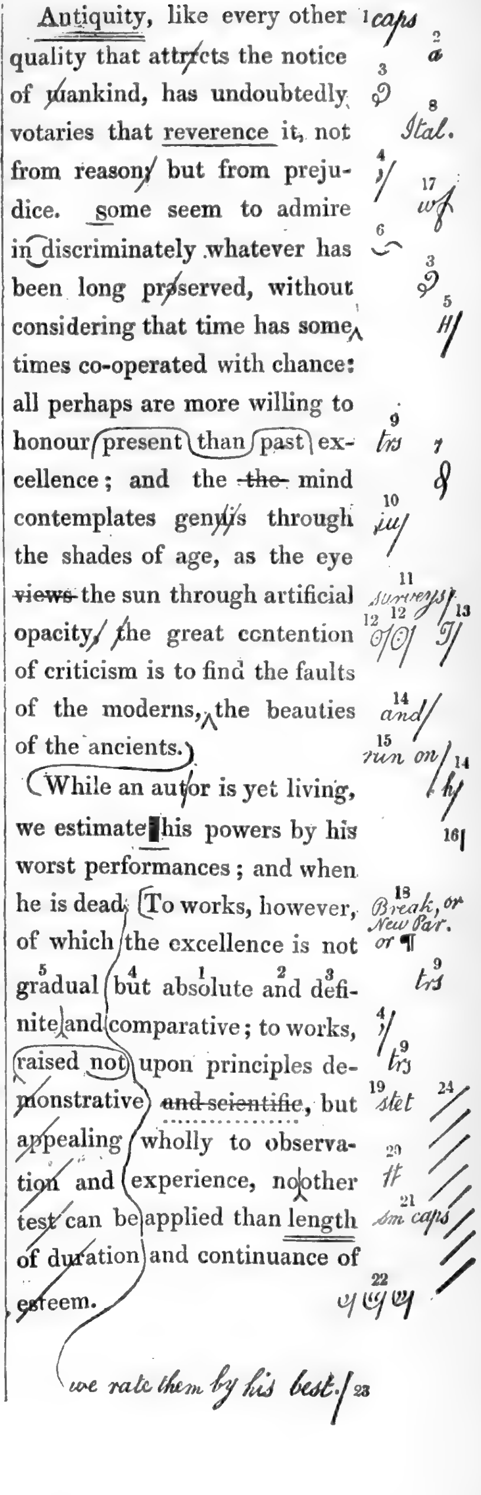
23. The manner of marking an omission, or an insertion, when it is too long to be written in the side margin. When this occurs it may be written either at the top or the bottom of the page.

24. Marks when lines or words are not straight.

The subjoined specimen, when corrected, would be as follows:—

ANTIQUITY, like every other quality that attracts the notice of mankind, has undoubtedly votaries that *reverence* it, not from reason, but from prejudice. Some seem to admire indiscriminately whatever has been long preserved, without considering that time has sometimes co-operated with chance: all perhaps are more willing to honour past than present excellence; and the mind contemplates genius through the shades of age, as the eye surveys the sun through artificial opacity. The great contention of criticism is to find the faults of the moderns, and the beauties of the ancients. While an author is yet living, we estimate his powers by his worst performances; and when he is dead, we rate them by his best.

To works, however, of which the excellence is not absolute and definite, but gradual and comparative; to works, not raised upon principles demonstrative and scientific, but appealing wholly to observation and experience, no other test can be applied than LENGTH of duration and continuance of esteem.



Antiquity, like every other quality that attrrcts the notice of ɯankind, has undoubtedly votaries that reverence it, not from reason/ but from prejudice. some seem to admire in discriminately whatever has been long prəserved, without considering that time has some times co-operated with chance: all perhaps are more willing to honour present than past excellence; and the ~~the~~ mind contemplates genuis through the shades of age, as the eye ~~views~~ the sun through artificial opacity, the great contention of criticism is to find the faults of the moderns, the beauties of the ancients.

While an autor is yet living, we estimate his powers by his worst performances; and when he is dead, To works, however, of which the excellence is not $\overset{5}{\text{gradual}}$ $\overset{4}{\text{but}}$ $\overset{1}{\text{absolute}}$ $\overset{2}{\text{and}}$ $\overset{3}{\text{definite}}$ and comparative; to works, raised not upon principles demonstrative ~~and scientific~~, but appealing wholly to observation and experience, noother test can be applied than length of duration and continuance of esteem.

When the reader has read his proof, it is handed to the compositor, who unlocks the form, and makes the corrections in the types, by lifting out the wrong letters by means of a sharp awl or *bodkin*, and putting in right ones in their places. The form is then locked up again, taken to the press, and another proof is *pulled*. This is termed *the revise*, and is sent to the reader, with his first proof, that he may see that all the corrections have been properly made, put queries against doubtful matters for the author's consideration, and send it, thenceforth called a *clean proof*, with the MS., to the author. When the author returns his proof and revise, and is satisfied that the sheet is correct, the form, after having been finally read with care for press, is taken to the press or machine to have the requisite number of impressions struck off. Before this is done, however, care is taken that the matter at the beginning of the sheet connects with that at the end of the preceding, that the pages are correct, and that the 'signatures' are in order. The signatures are generally small capital letters, placed at the foot of the first page of each sheet, commencing with B, and omitting the J, V, and W. They are said to have been first used by John Koelhof, at Cologne, in 1472; but they exist in an edition of 'Terence,' printed by Antonio Zorac, at Milan, in 1470. There is a Venetian edition of 'Baldi Lectura super Codic,' &c., printed by John de Colonia and Jo. Manthen de Gherretzem, in 1474, in which it is evident that these printers had only just become acquainted with the use of signatures, as these marks were not introduced till one-half of the work had been printed. The following Tables show the signatures and folios of any given number of sheets in 8vo, 12mo, and 18mo.

The paper used in printing is always damped before being sent to the press, wet paper taking the ink considerably better than dry. The warehouseman delivers the proper quantity of paper to the wetter, which is wetted thus:—The quire of paper is opened, its back broken, and divided into three, four, or five portions, or *dips*, drawn through a trough of clean water and laid on a board, dip after dip, till a convenient heap is made. This is put into a screw press, a little pressure applied, and the next day the whole is *turned* and slightly pressed again, so that fresh surfaces of the paper coming into contact, the moisture is equally diffused throughout the heap. The paper used in printing is of three kinds: *imperfect paper*, consisting of 20 quires of 24 sheets, or 480 sheets to the ream; *perfect paper* (that most generally used) consisting of 21½ quires, or 516 sheets; and *news paper*, consisting of 20 quires of 25 sheets each to the ream, or 500 sheets. The *stamped sheets* of newspaper (generally called *stamps*, and the plain paper *blanks*) are always received and delivered by the nett number without allowing for spoilage in the press-work; but in book-work it is the

SHEET OF OCTAVO.

No. of sheets	Signature	Folio	No. of sheets	Signature	Folio	No. of sheets	Signature	Folio	No. of sheets	Signature	Folio
			23	2 A	353	46	3 A	721	69	4 A	1089
1	B	1	24	B	369	47	B	737	70	B	1105
2	C	17	25	C	385	48	C	753	71	C	1121
3	D	33	26	D	401	49	D	769	72	D	1137
4	E	49	27	E	417	50	E	785	73	E	1153
5	F	65	28	F	433	51	F	801	74	F	1169
6	G	81	29	G	449	52	G	817	75	G	1185
7	H	97	30	H	465	53	H	833	76	H	1201
8	I	113	31	I	481	54	I	849	77	I	1217
9	K	129	32	K	497	55	K	865	78	K	1233
10	L	145	33	L	513	56	L	881	79	L	1249
11	M	161	34	M	529	57	M	897	80	M	1265
12	N	177	35	N	545	58	N	913	81	N	1281
13	O	193	36	O	561	59	O	929	82	O	1297
14	P	209	37	P	577	60	P	945	83	P	1313
15	Q	225	38	Q	593	61	Q	961	84	Q	1329
16	R	241	39	R	609	62	R	977	85	R	1345
17	S	257	40	S	625	63	S	993	86	S	1361
18	T	273	41	T	641	64	T	1009	87	T	1377
19	U	289	42	U	657	65	U	1025	88	U	1393
20	X	305	43	X	673	66	X	1041	89	X	1409
21	Y	321	44	Y	689	67	Y	1057	90	Y	1425
22	Z	337	45	Z	705	68	Z	1073	91	Z	1441

Sheet of Twelves.

No. of sheets	Signature	Folio	No. of sheets	Signature	Folio	No. of sheets	Signature	Folio
			23	2 A	529	46	3 A	1081
1	B	1	24	B	553	47	B	1105
2	C	25	25	C	577	48	C	1129
3	D	49	26	D	601	49	D	1153
4	E	73	27	E	625	50	E	1177
5	F	97	28	F	649	51	F	1201
6	G	121	29	G	673	52	G	1225
7	H	145	30	H	697	53	H	1249
8	I	169	31	I	721	54	I	1273
9	K	193	32	K	745	55	K	1297
10	L	217	33	L	769	56	L	1321
11	M	241	34	M	793	57	M	1345
12	N	265	35	N	817	58	N	1369
13	O	289	36	O	841	59	O	1393
14	P	313	37	P	865	60	P	1417
15	Q	337	38	Q	889	61	Q	1441
16	R	361	39	R	913	62	R	1465
17	S	385	40	S	937	63	S	1489
18	T	409	41	T	961	64	T	1513
19	U	433	42	U	985	65	U	1537
20	X	457	43	X	1009	66	X	1561
21	Y	481	44	Y	1033	67	Y	1585
22	Z	505	45	Z	1057	68	Z	1609

Sheet of Eighteens.

No. of sheets	Signature	Folio	No. of sheets	Signature	Folio	No. of sheets	Signature	Folio
				2 A	265	16	3 A	541
1	B	1		B	277		B	553
	C	13	9	C	289		C	565
	D	25		D	301	17	D	577
2	E	37		E	313		E	589
	F	49	10	F	325		F	601
	G	61		G	337	18	G	613
3	H	73		H	349		H	625
	I	85	11	I	361		I	637
	K	97		K	373	19	K	649
4	L	109		L	385		L	661
	M	121	12	M	397		M	673
	N	133		N	409	20	N	685
5	O	145		O	421		O	697
	P	157	13	P	433		P	709
	Q	169		Q	445	21	Q	721
6	R	181		R	457		R	733
	S	193	14	S	469		S	745
	T	205		T	481	22	T	757
7	U	217		U	493		U	769
	X	229	15	X	505		X	781
	Y	241		Y	517	23	Y	793
8	Z	253		Z	529		Z	805

practice to allow 16 sheets in each ream for 'tympan-sheet' and spoiled sheets. The following Table shows the quantity of perfect and imperfect paper required for one sheet of 16 pages of a work like 'Ure's Dictionary,' from 12 to 10,000 copies:—

Quantity required of *perfect* paper			Quantity required of *imperfect* paper			For printing 1 sheet of 16 pages	Total number of copies the paper will make
reams	quires	sheets	reams	quires	sheets	copies	
0	0	15	0	0	15	12	15
0	1	4	0	1	4	25	28
0	2	6	0	2	6	50	54
0	3	7	0	3	7	75	79
0	4	8	0	4	8	100	104
0	5	9	0	5	9	125	129
0	6	12	0	6	12	150	156
0	7	13	0	7	13	175	181
0	8	14	0	8	14	200	206
0	10	18	0	10	18	250	258
0	12	22	0	12	22	300	310
0	15	0	0	15	0	350	360
0	16	3	0	16	3	375	387
0	17	4	0	17	4	400	412
0	19	6	0	19	6	450	462
1	0	0	1	1	12	500	516
1	4	6	1	5	18	600	618
1	8	14	1	10	2	700	722
1	10	18	1	12	6	750	774
1	13	0	1	14	10	800	826
1	17	4	1	18	17	900	928
2	0	0	2	3	0	1,000	1,032
2	10	18	2	13	18	1,250	1,290
3	0	0	3	4	12	1,500	1,548
3	18	18	3	15	6	1,750	1,806
4	0	0	4	6	0	2,000	2,064
6	0	0	6	9	0	3,000	3,096
8	0	0	8	12	0	4,000	4,128
10	0	0	10	15	0	5,000	5,160
12	0	0	12	18	0	6,000	6,192
14	0	0	15	1	0	7,000	7,224
16	0	0	17	4	0	8,000	8,256
18	0	0	19	7	0	9,000	9,288
20	0	0	21	10	0	10,000	10,320

Press-work.—The pressman first lays the inner form on the press, and prints one copy, which is called a *press revise*; this he takes to the person appointed to revise it, and while that is being done proceeds to secure the form on the table of the press by means of quoins; to place his tympan-sheet; to fix the points which make small holes in the paper that enable him to cause the pages to fall precisely on the back of each other when the second side of the paper is printed, and to produce an even and uniform impression in all the pages. He then cuts his frisket, which preserves the margin of the paper clean, and, when the revise is corrected, proceeds to ink the surface of the types by means of rollers. When the whole impression of one side of the paper is printed, he lifts the form off the press, washes the ink off the face of the type with lye, and rinses it with water. He then proceeds in a similar manner with the outer form, which completes the sheet. This process is continued sheet after sheet till the work is complete.

When the sheet is printed the compositor lays it up, distributes the type, and proceeds, sheet after sheet, till the body of the work is finished; then the title, dedication, preface, introduction, contents, index, and any other prefatory matter is proceeded with, these being always printed the last. This distribution of the types, or putting back the letters into the several compartments of the case where they belong, is performed with the greatest rapidity. The compositor wets the whole page or form, and takes up a number of lines on his composing rule. This wetting causes the types to adhere slightly together, and renders the manipulation easy. He then takes up a few words between his right-hand finger and thumb, and by a dexterous motion he throws off the several letters into their various boxes. Distribution is performed four times faster than composition.

After the sheets have been printed on both sides, the warehouseman takes them away, and hangs them up on poles to dry, varying the number of sheets hung up together from five or six to ten or eleven, according to the heat of the room, or the pressure of business. When dry the sheets are taken down from the poles, carefully knocked up and put away in the warehouse in piles; and when the book is nearly finished from ten to fourteen consecutive sheets are laid upon the gathering-board in order, and collected sheet by sheet by boys, who deposit each *gathering* in a heap at the end of the table, so constructed that when a boy has deposited his gathering he has only to turn himself and begin again. These gatherings are then carefully *collated*, to ascertain that the different sheets are correct and in order, and folded up the middle. When the work is finished the gatherings are put together, or *in books*, one of each, which forms a copy of the work, and pressed. The work is now completed, and awaits the order of the bookseller, &c., to deliver the copies to the bookbinder.

Printing in Colours.—In many of the old printed books, the initial letters, and occasionally other parts, were printed in red. This was done by two workings at press, and was an imitation of the earlier fashion of illuminating MSS. The practice is still followed in some almanacs, the saints' days and holidays being 'red-letter days.' Some ingenious contrivances have been devised for working in various colours; and a few years since a curious book was written and published on the subject by Mr. Savage. Still more recently, printing in gold and other metals has been practised. This is done by printing with a sort of size, and afterwards applying the metal-leaf. But the specimens of printing in colours produced by Mr. Kronheim are really beautiful as works of art. The copy picture is made in colours, and the blocks for printing each colour and shade are cut in relief on 'surface metal' plates, consisting of perfectly smooth plates of type-metal. These plates are then printed by the ordinary method, great care, however, being taken that each colour falls in its right place.

The following is the mode of printing two or more 'rainbow tints' at the same time:—Take the cut, ink it well and rather full, with black ink, and get a perfect impression on paper not very damp; then lay the face of the printed paper carefully on the surface of the block prepared for engraving the whites on the tinted ground, and give it a good soft pull. This will transfer to the tint block a facsimile of the wood-engraving itself. This block is then handed over to the engraver, who cuts out the whites for the clouds, shadows, water, &c., according to his taste, and with a view to effect. The tint-block is printed first, and then the black block is put to press, and the pressman must be careful in distributing his different inks to make them fade away and blend at the given points. This is an easy matter after a little practice.

Laws affecting the Press.—As to the laws relating to the press, see 39 Geo. III. c. 79, amended by 51 Geo. III. c. 65, and 2 & 3 Vict. c. 12. There is no censorship over the press; which is, however, amenable to the remedy of an injured party, or to the correction of criminal justice (*Wharton's Law Lex.* 2nd ed. 1860).—R. J. C.

PRINTING BLOCKS—ELECTRO. Two patents taken out by Mr. H. G. Collins are likely to prove of essential service to the publishing world. By the one he is enabled to take on vulcanised caoutchouc, prepared with an equally elastic surface, an impression in transfer from any steel- or copper-plate, wood-block, stereotype, lithographic-stone, or, in fact, from an original drawing, if done in transfer-ink or transfer-paper, and increase or reduce the same to any required size. This is effected by expanding the india-rubber in one case, after it has received the impression; and in the other, before the impression is made. In the first instance, the impression is enlarged as the elastic material expands; in the other it is reduced by allowing the already expanded india-rubber to contract in its frame: then laying the expanded or contracted copy down upon stone, and treating it after the usual manner of lithography. This presents a vast field for adapting the plates of any work of acknowledged merit which may have cost some hundreds or thousands of pounds, and years to produce, to the wants of the public in these days of cheap and well-illustrated literature, by bringing out the same works in a reduced size, which, but for this plan, no publisher would think of attempting. Many plates also, such as portraits, public buildings, or landscapes, may be enlarged and issued separately. This last application is particularly suitable for maps, as any one, from the size of a school atlas, may be taken and made to serve for large wall-maps without the cost of engraving the same. The rapidity with which this alteration of size can be accomplished is not among the least of its recommendations; for an engraving that would take several months in the ordinary mode may be completed in from two to three days. Two remarkable instances of the excellent reductions obtainable by this process are given in the square 16mo. editions of Moore's 'Melodies' and Macaulay's 'Lays of Ancient Rome,' published by Messrs. Longman & Co.

This patent offers the same facilities to a vast number of the manufactures of the country, such as the lace trade, cotton printers, damask and moreen houses, potteries, paper-hangings; in fact, to all or every one who employ *art* or *design* in their calling. It will be well to observe that the size can not only be enlarged or diminished, as the case may be, but the pattern can be altered in form; thus a circular design can be made into an oval, if required. Mr. Collins, by his second patent, is enabled, after these impressions are once upon the stone, to make them into electro-blocks, thus reducing also the cost of printing engraved plates, which is effected in the following manner:—The impression being placed on the lithographic-stone or the zinc-plate—either one or the other can be employed—acid is applied to abrase to a certain extent the stone or metal over the unprotected portions; when this is sufficiently deep a mould is taken in wax, the surface of which being prepared is subjected to the electrotype process, and thus a copper-block is obtained. See PHOTOZINCOGRAPHY.

PRINTING INK. (*Encre d'imprimerie*, Fr.; *Buchdruckerfarbe*, Ger.) After reviewing the different prescriptions given by Moxon, Breton, Papillon, Lewis, those in Nicholson's and the Messrs. Aikins' Dictionaries, in Rees's Cyclopædia, and in the French Printer's Manual, Mr. Savage[1] says, that the *Encyclopædia Britannica* is the only work, to his knowledge, which has given a recipe by which a printing ink might be made that could be used, though it would be of inferior quality, as acknowledged by the editor: for it specifies neither the qualities of the materials, nor their due proportions. The fine black ink made by Mr. Savage has, he informs us, been pronounced by some of our first printers to be unrivalled, and has procured for him the large medal from the Society for the Encouragement of Arts.

1. *Linseed-oil.*—Mr. Savage says that the linseed-oil, however long boiled, unless set fire to, cannot be brought into a proper state for forming printing ink; and that the flame may be most readily extinguished by the application of a pretty tight tin cover to the top of the boiler, which should never be more than half full. The French prefer nut-oil to linseed; but if the latter be old, it is fully as good, and much cheaper, in this country at least.

2. *Black rosin* is an important article in the composition of good ink; as by melting it in the oil, when that ingredient is sufficiently boiled and burnt, the two combine, and form a compound approximating to a natural balsam, like that of Canada.

3. *Soap.*—This is a most important ingredient in printer's ink, which is not even mentioned in any of the recipes prior to that in the *Encyclopædia Britannica.* For want of soap, ink accumulates upon the face of the types, so as completely to clog them up after comparatively few impressions have been taken; it will not wash off without alkaline lyes, and it skins over very soon in the pot. Yellow rosin-soap is the best for black inks; for those of light and delicate shades, white curd-soap is preferable. Too much soap is apt to render the impression irregular, and to prevent the ink from drying quickly. The proper proportion has been hit when the ink works clean, without clogging the surface of the types.

4. *Lamp-black.*—The vegetable lamp-black sold in firkins takes by far the most varnish, and answers for making the best ink. See BLACK.

5. *Ivory-black* is too heavy to be used alone as a pigment for printing ink; but it may be added with advantage by grinding a little of it upon a muller with the lamp-black, for certain purposes; for instance, if an engraving on wood is required to be printed so as to produce the best possible effect. See IVORY-BLACK.

6. *Indigo* alone, or with an equal weight of Prussian blue, added in small proportion, takes off the brown tone of certain lamp-black inks. Mr. Savage recommends a little Indian red to be ground in with the indigo and Prussian blue, to give a rich tone to the black ink.

7. *Balsam of copaiba*, mixed, by a stone and a muller with a due proportion of soap and pigment, forms an extemporaneous ink, which the printer may employ very advantageously when he wishes to execute a job in a peculiarly neat manner.

After the smoke begins to rise from the boiling oil, a bit of burning paper stuck in the cleft end of a long stick should be applied to the surface, to set it on fire, as soon as the vapour will burn; and the flame should be allowed to continue (the pot being meanwhile removed from over the fire, or the fire taken from under the pot) till a sample of the varnish, cooled upon a pallet-knife, draws out the strings of about half an inch long between the fingers. To 6 quarts of linseed-oil thus treated, 6 pounds of rosin should be gradually added, as soon as the froth of the ebullition has subsided. Whenever the rosin is dissolved, one pound and three quarters of dry brown soap, of the best quality, cut into slices, is to be introduced cautiously, for its water of combination causes a violent intumescence. Both the rosin and soap should be well stirred with a spatula. The pot is to be now set upon the fire again, in order to complete the combinations of all the constituents.

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[1] In his work on the Preparation of Printing Ink; 8vo., London, 1832.

Put next of well-ground indigo and Prussian blue, each 2½ ounces, into an earthen pan, sufficiently large to hold all the ink, along with 4 pounds of the best mineral lamp-black, and 3½ pounds of good vegetable lamp-black; then add the warm varnish by slow degrees, carefully stirring, to produce the perfect incorporation of all the ingredients. This mixture is next to be subjected to a mill, or slab and muller, till it be levigated into a smooth, uniform paste.

One pound of a superfine printing ink may be made by the following recipe of Mr. Savage:—Balsam of copaiba, 9 oz.; lamp-black, 3 oz.; indigo and Prussian blue together, p. æq. $1\frac{1}{4}$ oz.; Indian red, $\frac{3}{4}$ oz.; turpentine (yellow) soap, dry, 3 oz. This mixture is to be ground upon a slab, with a muller, to an impalpable smoothness. The pigments used for colouring printing inks are: carmine, lakes, vermilion, red lead, Indian red, Venetian red, chrome yellow, chrome red or orange, burnt *terra di Sienna*, gall-stone, Roman ochre, yellow ochre, verdigris, blues and yellows mixed for greens, indigo, Prussian blue, Antwerp blue, umber, sepia, &c.

PRINTING MACHINE. (*Typographie mécanique*, Fr.; *Druckmaschine*, Ger.) No improvement had been introduced in these important machines, from the invention of the art of printing, till the year 1798, a period of nearly 350 years. In Dr. Dibdin's interesting account of printing, in the *Bibliographical Decameron*, may be seen representations of the early printing presses, which exactly resemble the wooden presses in use a few years back.

For the first essential modification of the old press, the world is indebted to the late Earl Stanhope. His press is formed of iron, without any wood; the table upon which the form of types is laid, as well as the *platen* or surface which immediately gives the impression, is of cast iron, made perfectly level; the platen being large enough to print a whole sheet at one pull. The compression is applied by a beautiful combination of levers, which give motion to the screw, cause the platen to descend with progressively increasing force till it reaches the type, when the power approaches the maximum; upon the infinite lever principle, the power being applied to straighten an obtuse-angle jointed lever. This press, however, like all its flat-faced predecessors, does not act by a continuous, but a reciprocating motion; nor does it much exceed the old presses in productiveness, since it can turn off only 250 impressions per hour; but it is capable of producing much finer press-work than any steam- or hand-machine yet invented, for this reason: the best work requires the best ink, which is stiff, and requires a longer time in distributing over and beating into the form of types than the thin, oily, and consequently browner ink required by the rapidly moving machine. It is a remarkable fact that the *Penny Magazine* was printed at the hand-press, although the editor assured his readers that the cylindrical form of machine was capable of printing the finest impressions from woodcuts. The machine, however, has the advantage of uniformity of colour in inking throughout a whole impression. The iron platen of the Stanhope press was supposed at one time to wear out types much sooner than the old wooden one, but experience does not warrant us in supporting this statement.

The first person who publicly projected a self-acting printing press was Mr. William Nicholson, the able editor of the *Philosophical Journal*, who obtained a patent in 1790: 1, for imposing types upon a cylindrical surface (see *fig.* 1675); 2, for applying the ink upon the surface of the types, &c., by causing the surface of a cylinder smeared with the colouring-matter to roll over them; or else causing the types to apply themselves to the cylinder. For the purpose of spreading the ink evenly over this cylinder, he proposed to apply three or more distributing rollers longitudinally against the inking-cylinder, so that they might be turned by the motion of the latter. 3. 'I perform,' he says, '*all my impressions by the action* of a cylinder or cylindrical surface; that is, I cause the paper to pass between two cylinders, one of which has the form of types attached to it, and forming part of its surface; and the other is faced with cloth, and serves to press the paper so as to take off an impression of the colour previously applied; or otherwise I cause the form of types, previously coloured, to pass in close and successive contact with the paper wrapped round a cylinder with woollen.' See *figs.* 1675 and 1676.[1]

The first operative printing machine was undoubtedly contrived by, and constructed under the direction of, M. König, a clock-maker from Saxony, who, so early as the year 1804, was occupied in improving printing presses. Having failed to interest the

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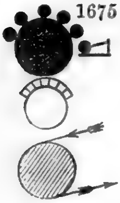
[1] The black parts in these little diagrams, 1675, 1676, indicate the inking apparatus; the diagonal lines, the cylinders upon which the paper to be printed is applied; the perpendicular lines, the plates or types; and the arrows show the track pursued by the sheet of paper.

Continental printers in his views, he came to London soon after that period, and submitted his plans to Mr. T. Bensley and Mr. G. Woodfall, well-known printers, and to Mr. R. Taylor, late one of the editors of the 'Philosophical Magazine.'

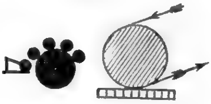
These gentlemen afforded Mr. König, and his assistant Bauer, a German mechanic, liberal pecuniary support. In 1811, he obtained a patent for a method of working a common hand-press by steam-power, and 3,000 copies of signature H of the 'New Annual Register' were printed by it; but, after much expense and labour, he was glad to renounce the scheme. He then turned his mind to the use of a cylinder for communicating the pressure, instead of a flat plate; and he finally succeeded, sometime before November 28, 1814, in completing his printing automaton; for on that day the editors of the 'Times' informed their readers that they were perusing for the first time a newspaper printed by steam-impelled machinery; it is a day, therefore, which will be ever memorable in the annals of typography.

1675



Nicholson's, for arched type.

1676

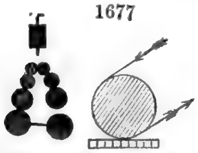


Nicholson's, for common type.

In that machine the form of type was made to traverse horizontally under the pressure-cylinder, with which the sheet of paper was held in close embrace by means of a series of endless tapes. The ink was placed in a cylindrical box, from which it was extruded by means of a powerful screw, depressing a well-fitted piston; it then fell between two iron rollers, and was by their rotation transferred to several other subjacent rollers, which had not only a motion round their axes, but an alternating traverse motion (endwise). This system of equalising rollers terminated in two, which applied the ink to the types. (See *fig.* 1677.) This plan of inking evidently involved a rather complex mechanism, was hence difficult to manage, and sometimes required two hours to get into good working trim.

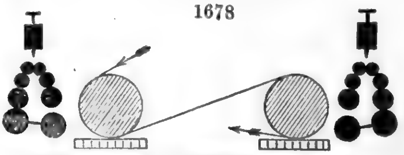
In order to obtain a great many impressions rapidly from the same form, a paper-conducting cylinder (one embraced by the paper) was mounted upon each side of the inking apparatus, the form being made to traverse under both of them. This double-action machine threw off 1,100 impressions per hour when first finished; and by a subsequent improvement, no less than 1,800

1677



König's single, for one side of the sheet.

1678

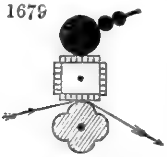


König's double, for both sides of the sheet.

Mr. König's next feat was the construction of a machine for printing both sides of the newspaper at each complete traverse of the forms. This resembled two single machines, placed with their cylinders towards each other, at a distance of two or three feet; the sheet was conveyed from one paper-cylinder to another, as before, by means of tapes; the track of the sheet exactly resembled the letter S laid horizontally, thus, ∽ ; and the sheet was turned over or reversed in the course of its passage. At the first paper-cylinder it received the impression from the first form, and at the second received it from the second form; whereby the machine could print 750 sheets of book letter-press on both sides in an hour. This new register apparatus was erected for Mr. T. Bensley, in the year 1815, being the only machine made by Mr. König for printing upon both sides. See *fig.* 1678.

Messrs. Donkin and Bacon had for some years previous to this date been busily engaged with printing machines, and had indeed, in 1813, obtained a patent for an apparatus, in which the types were placed upon the sides of a revolving prism; the ink was applied by a roller, which rose and fell with the eccentricities of the prismatic surface, and the sheet was wrapped upon another prism fashioned so as to coincide with the eccentricities of the type-prism. One such machine was erected for the University of Cambridge. (See *fig.* 1679.) It was a beautiful specimen of ingenious contrivance and good workmanship. Though it was found to be too complicated for common operatives, and defective in the mechanism of the

1679

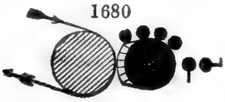


Donkin and Bacon's, for type.

inking process, yet it exhibited for the first time the elastic inking-rollers, composed of glue combined with treacle, which alone constitute one of the finest inventions of modern typography.

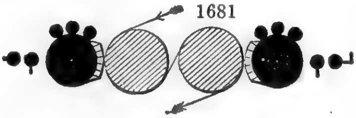
In the year 1815, Mr. Cowper turned his mind to the subject of printing machines, and in co-operation with his partner, Mr. Applegath, carried them to an unlooked-for degree of perfection. In 1816, Mr. Cowper obtained a patent for curving stereotype-plates, for the purpose of fixing them on a cylinder. Several machines so mounted, capable of printing 1,000 sheets per hour upon both sides, are at work at the present day. (See *figs.* 1680 and 1681.) In these machines, Mr. Cowper places two paper-cylinders side by side, and against each of them a cylinder for holding the plates; each of these four cylinders is about two feet in diameter. Upon the surface of the stereotype-plate cylinder, four or five inking-rollers of about three inches in diameter are placed; they are kept in their position by a frame at each end of the said cylinder, and the axles of the rollers rest in vertical slots of the frame, whereby having perfect freedom of motion, they act by their gravity alone, and require no adjustment.

1680



Cowper's single, for curved stereotype.

1681



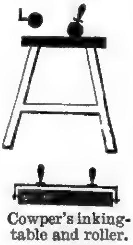
Cowper's double, for both sides of the sheet.

The frame which supports the inking-rollers, called the waving-frame, is attached by hinges to the general framework of the machine; the edge of the stereotype-plate cylinder is indented, and rubs against the waving-frame, causing it to vibrate to and fro, and consequently to carry the inking-rollers with it, so as to give them an unceasing traverse movement. These rollers distribute the ink over three-fourths of the surface of the cylinder, the other quarter being occupied by the curved stereotype-plates. The ink is contained in a trough, which stands parallel to the said cylinder, and is formed by a metal roller revolving against the edge of a plate of iron; in its revolution it gets covered with a thin film of ink, which is conveyed to the plate-cylinder by a distributing roller vibrating between both. The ink is diffused upon the plate-cylinder, as before described; the plates in passing under the inking rollers become charged with the coloured varnish; and as the cylinder continues to revolve, the plates come into contact with a sheet of paper on the first paper-cylinder, which is then carried by means of tapes to the second paper-cylinder, where it receives an impression upon its opposite side from the plates upon the second cylinder. Thus the printing of the sheet is completed.

In order to adapt this method of inking to a flat type-form machine, it was merely requisite to do the same thing upon an extended flat surface or table, which had been performed upon an extended cylindrical surface. Accordingly, Messrs. Cowper and Applegath constructed a machine for printing both sides of the sheet from type, including the inking apparatus, and the mode of conveying the sheet from the one paper-cylinder to the other, by means of drums and tapes. It is highly creditable to the scientific judgment of these patentees, that in new-modelling the printing machine, they dispensed with forty wheels, which existed in Mr. König's apparatus when Mr. Bensley requested them to apply their improvements to it.

The distinctive advantages of these machines, and which have not hitherto been equalled, are the uniform distribution of the ink, the equality as well as delicacy with which it is laid upon the types, the diminution in its expenditure, amounting to one half upon a given quantity of letter-press, and the facility with which the whole mechanism is managed. The hand inking-roller and distributing-table, now so common in every printing-office in Europe and America, is the invention of Mr. Cowper, and was specified in his patent. The vast superiority of the inking apparatus in his machines over the balls used of old, induced him to apply it forthwith to the common press, and most successfully. See *fig.* 1682.

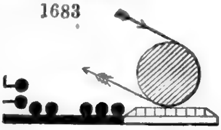
1682



Cowper's inking-table and roller.

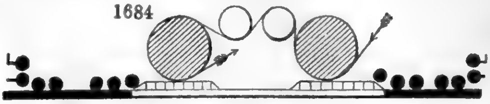
To construct a printing machine which shall throw off two sides at a time with exact register, that is, with the second side placed precisely upon the back of the first, is a very difficult problem, which was practically solved by Messrs. Applegath and Cowper. It is comparatively easy to make a machine which shall print the one side of a sheet of paper first, and then the other side, by the removal of one form, and the introduction of another; and thus far did Mr. König advance. A correct register requires the sheet, after it has received its first impression from one cylinder, to travel round the peripheries of the cylinders and drums, at such a rate as to meet the types of the second side at the exact point which will ensure this side falling with geometrical nicety upon the back of the first. For this purpose, the cylinders and drums must revolve at the very same speed as the carriage underneath; hence the least incorrectness in the workmanship will produce such defective typography as will not be endured in book-printing at the present day, though it may be tolerated in newspapers. An equable distribution of the ink is of no less importance to beautiful letter-press. See *figs.* 1683, 1684.

1683



Applegath and Cowper's single.

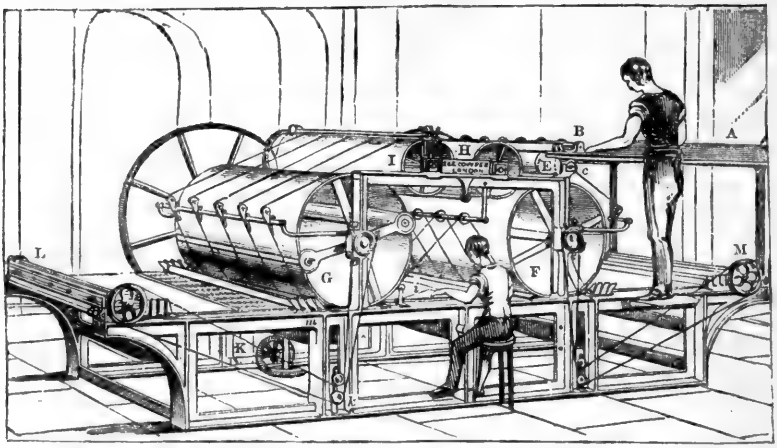
1684



Applegath and Cowper's double.

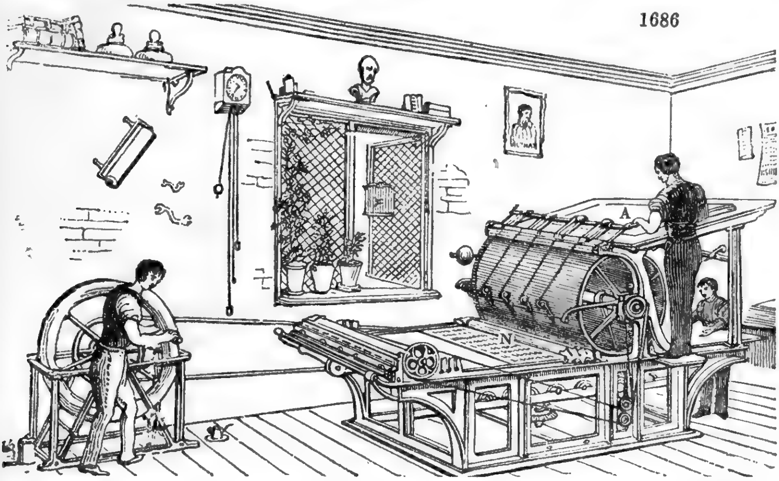
The machines represented in *figs.* 1685, 1686, 1687, are different forms of those which have been patented by Messrs. Applegath and Cowper. That shown in *figs.* 1685, 1687, prints both sides of the sheet during its passage, and is capable of throwing off nearly 1,000 finished sheets per hour. The moistened quires of blank paper being piled upon a table, A, the boy, who stands on the adjoining platform, takes up one sheet after another, and lays them upon a feeder B, which has several linen girths passing across its surface, and round a pulley at each end of the feeder; so that whenever the pulleys begin to revolve, the motion of the girths carries forward the sheet, and delivers it over the entering roller E, where it is embraced between two series of endless tapes, that pass round a series of tension rollers. These tapes are so placed as to fall partly between, and partly exterior to, the pages of the printing; whereby they remain in close contact with the sheet of paper on both of its sides during its progress through the machine. The paper is thus conducted from the first printing-cylinder F, to the second cylinder G, without having the truth of its register impaired, so that the coincidence of the two pages is perfect. These two great cylinders, or drums, are made of cast iron, turned perfectly true upon a self-acting lathe; they are clothed in these parts, corresponding to the typographic impression, with fine woollen cloth, called *blankets* by the pressmen, and revolve upon powerful shafts, which rest in brass bearings of the strong framing of the machine. These bearings, or plummer blocks, are susceptible of any degree of adjustment, by set screws. The drums, H and I, are made of wood; they serve to conduct the sheet evenly from the one printing-cylinder to the other.

1685



One series of tapes commences at the upper part of the entering drum E, proceeds in contact with the right-hand side and under surface of the printing-cylinder F, passes next over the carrier-drum H, and under the carrier-drum I; then encompassing the left-hand side and under portion of the printing-drum G, it passes in contact with the small tension rollers *a*, *b*, *c*, *d*, *fig.* 1687, and finally arrives at the roller E, which may be called the commencement of the one series of endless tapes. The other series may be supposed to commence at the roller *h*; it has an equal number of tapes, and corresponds with the former in being placed upon the cylinders so that the sheets of paper may be held securely between them. This second series descends from the roller *h*, *fig.* 1687, to the entering drum E, where it meets and coincides with the first series in such a way that both sets of tapes proceed together *under* the printing cylinder F, *over* H, *under* I, and *round* G, until they arrive at the roller *i*, *fig.* 1685, where they separate, after having continued in contact, except at the places where the sheets of paper are held between them. The tapes descend from the roller *i*, to a roller at *k*, and, after passing in contact with rollers at *l*, *m*, *n*, they finally arrive at the roller *h*, where they were supposed to commence. Hence two series of tapes act invariably in contact, without the least mutual interference.

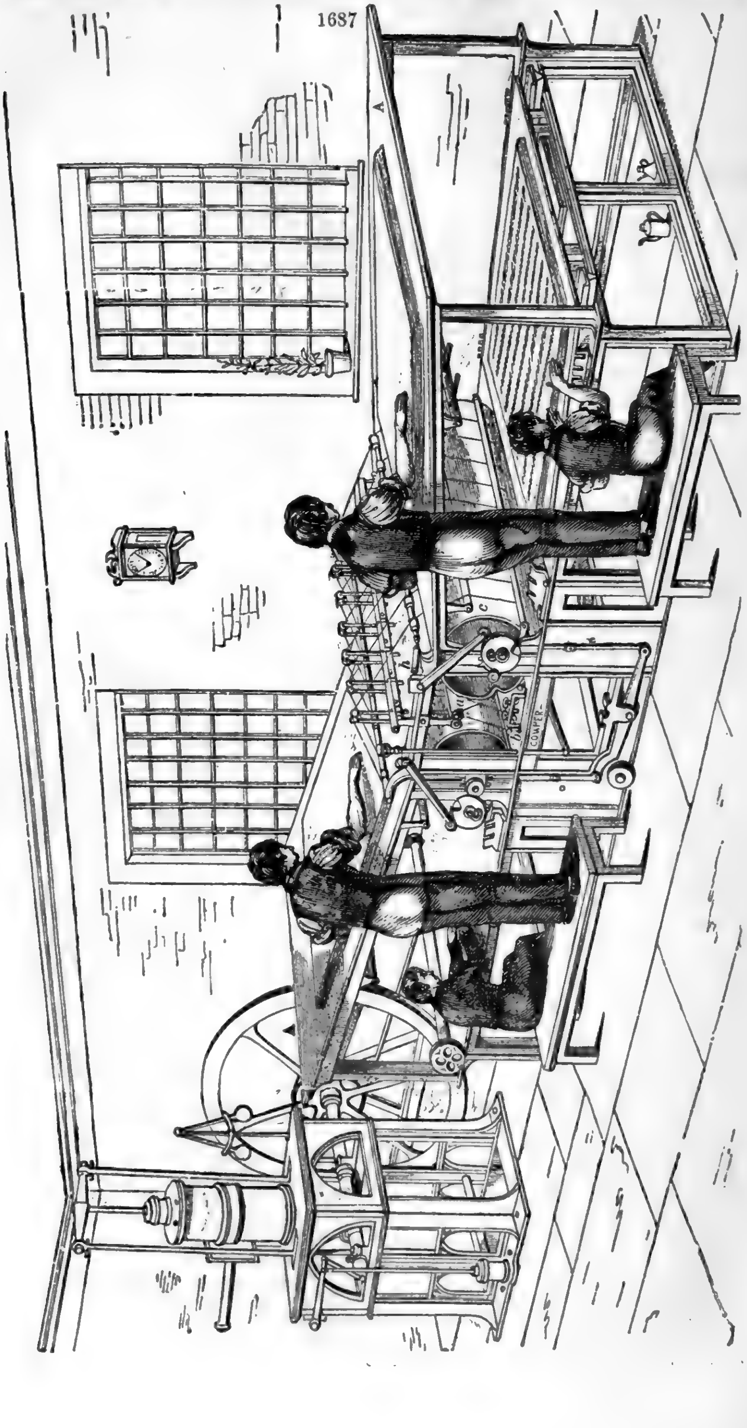
1686



The various cylinders and drums revolve very truly by means of a system of toothed wheels and pinions mounted at their ends. Two horizontal forms of types are laid at a certain distance apart upon the long carriage M, adjoining to each of which there is a flat metallic plate, or inking-table, in the same plane. The common carriage, bearing its two forms of type and two inking-tables, is moved backwards and forwards, from one end of the printing machine to the other, upon rollers attached to the frame-work, and in its traverse brings the types into contact with the sheet of paper clasped by the tapes round the surfaces of the printing cylinders. This alternate movement of the carriage is produced by a pinion working alternately into the opposite sides of a rack under the table. The pinion is driven by the bevel wheels K.

The mechanism for supplying the ink, and distributing it over the forms, is one of the most ingenious and valuable inventions belonging to this incomparable machine, and is so nicely adjusted that a single grain of the pigment may suffice for printing one side of a sheet. Two similar sets of inking apparatus are provided; one at each end of the machine, adapted to ink its own form of type. The metal roller L, called the *ductor* roller, as it draws out the supply of ink, has a slow rotatory motion communicated to it by a catgut cord, which passes round a small pulley upon the end of the shaft of the printing cylinder G. A horizontal plate of metal, with a straight-ground edge, is adjusted by set screws, so as to stand nearly in contact with the ductor roller. This plate has an upright ledge behind, converting it into a sort of trough or magazine, ready to impart a coating of ink to the roller, as it revolves over the table. Another roller, covered with elastic composition (see *supra*), called the vibrating roller, is made to travel between the ductor roller and the inking-table; the vibrating roller, as it rises, touches the ductor roller for an instant, abstracts a film of ink from it, and then descends to transfer it to the table. There are three or four small rollers of distribution, placed somewhat diagonally across the table at M (included only two inches from a parallel to the end of the frame), furnished with long slender axles, resting in vertical slots, whereby they are left at liberty to revolve and to traverse at the same time; by which compound movement they are enabled to efface all inequality in the surface of the varnish, or to effect a perfect distribution of the ink along the table. The table thus evenly smeared, being made to pass under the three or four proper inking-rollers, N, *fig*. 1687, imparts to them an

1687



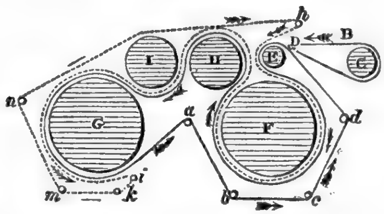
uniform film of ink, to be immediately transferred by them to the types. Hence each time that the forms make a complete traverse to and fro, which is requisite for the printing of every sheet, they are touched no less than eight times by the inking-rollers. Both the distributing- and inking-rollers turn in slots, which permit them to rise and fall so as to bear with their whole weight upon the inking-table and the form, whereby they never stand in need of any adjustment by screws, but are always ready for work when dropped into their respective places.

Motion is given to the whole system of apparatus by a strap from a steam-engine going round a pulley placed at the end of the axle at the back of the frame.

The operation of printing is performed as follows (see *fig.* 1688):—

The sheets being carefully laid, one by one, upon the linen girths, at the feeder B, the rollers C and D are made to move, by means of a segment wheel, through a portion of a revolution. This movement carries on the sheet of paper sufficiently to introduce it between the two series of endless tapes at the point where they meet each other upon the entering drum E. As soon as the sheet is fairly embraced between the tapes, the rollers C and D are drawn back, by the operation of a weight, to their original position, so as to be ready to introduce another sheet into the machine. The sheet, advancing between the endless tapes, applies itself to the blanket upon the printing cylinder F, and as it revolves meets the first form of types, and receives their impression; after being thus printed on one side, it is carried over H and under I, to the blanket upon the printing cylinder G, where it is placed in an inverted position; the printed side being now in contact with the blanket, and the white side being outwards, meets the second form of types at the proper instant, so as to receive the second impression, and get completely printed. The perfect sheet, on arriving at the point *i*, where the two series of tapes separate, is tossed out by centrifugal force into the hands of a boy.

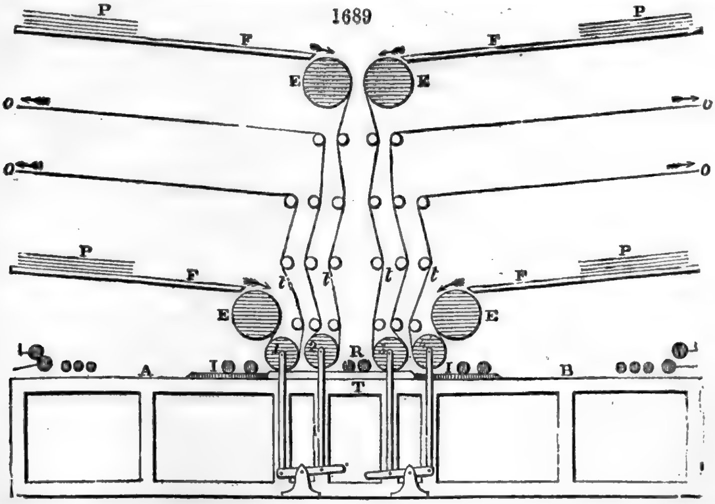
1688



The diagram, *fig.* 1688, shows the arrangement of the tapes, agreeably to the preceding description; the feeder B, with the rollers C and D, is seen to have an independent endless girth.

The diagram, *fig.* 1689, explains the structure of a machine contrived by Messrs. Applegath and Cowper for printing 'The Times' newspaper; but which is now superseded by Mr. Applegath's Vertical Printing Machine. Here there are four places to lay on the sheets, and four to take them off; consequently, the assistance of eight lads is required. P, P, P, P, are the four piles of paper; F, F, F, F, are the four feeding-boards;

1689



E, E, E, E, are the four entering drums, upon which the sheets are introduced between the tapes *t*, *t*, *t*, *t*, whence they are conducted to the four printing cylinders, 1, 2, 3, 4;

T is the form of type; I, I, are two inking-tables; of which one is placed at each end of the form. The inking apparatus is similar to that above described, with the addition of two central inking-rollers R, which likewise receive their ink from the inking-tables. The printing cylinders 1, 2, 3, 4, are made to rise and fall about half an inch; the first and third simultaneously, as also the second and fourth. The form of type, in passing from A to B, prints sheets at 1 and 3; in returning from B to A, it prints sheets at 4 and 2; while the cylinder alternately falls to give the impression, and rises to permit the form to pass untouched.

Each of the lines marked *t*, consists of two endless tapes, which run in contact in the parts shown, but separate at the entering drums E, and at the taking-off parts *o, o, o, o.* The return of the tapes to the entering drum is omitted in the diagram, to avoid confusion of the lines.

The sheets of paper being laid upon their respective feeding-boards, with the fore edges just in contact with the entering drum, a small roller, called the drop-down roller, falls down at proper intervals, upon the edges of the sheets; the drum and the roller being then removed, instantly carry on the sheet, between the tapes *t*, downwards to the printing cylinder, and thence upwards to *o, o, o, o,* where the tapes are parted, and the sheet falls into the hands of the attendant boy.

This invention fully answered the purpose of 'The Times' until the immense demand upon its powers rendered it necessary to provide a machine which could *work off from* 12,000 to 15,000 *copies of the paper per hour.*

Mr. Applegath, to whom the world is indebted for the invention of the printing machine capable of doing this large duty, decided on abandoning the reciprocating motion of the type-form, and arranging the apparatus so as to render the motion continuous. This necessarily involved circular motion, and accordingly he resolved upon attaching the columns of type to the sides of a large drum or cylinder, placed with its axis vertical, instead of the horizontal frame which had been hitherto used. A large central drum is erected, capable of being turned round its axis. Upon the sides of this drum are placed vertically the columns of type. These columns, strictly speaking, form the sides of a polygon, the centre of which coincides with the axis of the drum, but the breadth of the columns is so small compared with the diameter of the drum, that their surfaces depart very little from the regular cylindrical form. On another part of this drum is fixed the inking-table. The circumference of this drum in 'The Times' printing machine measures 200 inches, and it is consequently 64 inches in diameter.

The general form and arrangement of the machine are represented in *fig.* 1690, where D is the great central drum which carries the types and inking-tables.

This drum is surrounded by eight cylinders, R, R, &c., also placed with their axes vertical, upon which the paper is carried by tapes in the usual manner. Each of these cylinders is connected with the drum by toothed wheels, in such a manner that their surfaces respectively must necessarily move at exactly the same velocity as the surface of the drum. And if we imagine the drum thus in contact with these eight cylinders to be put in motion, and to make a complete revolution, the type-form will be pressed successively against each of the eight cylinders, and if the type were previously inked, and each of the eight cylinders supplied with paper, eight sheets of paper would be printed in one revolution of the drum.

It remains, therefore, to explain, first, how the type is eight times inked in each revolution; and secondly, how each of the eight cylinders is supplied with paper to receive their impression.

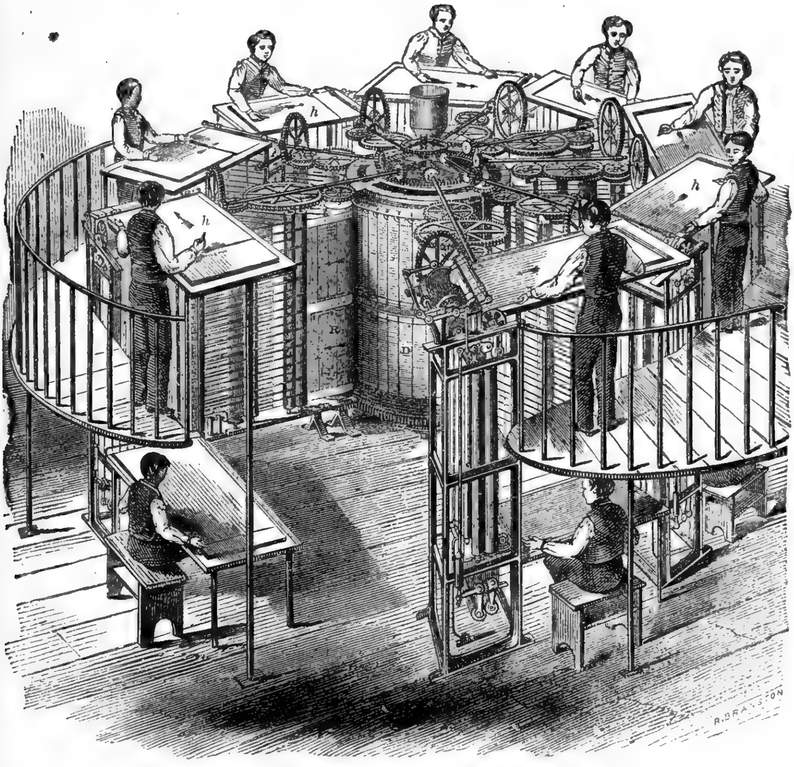
Beside the eight paper-cylinders are placed eight sets of inking-rollers; near these are placed two ductor rollers. These ductor rollers receive a coating of ink from reservoirs placed above them. As the inking-table attached to the revolving drum passes each of these ductor rollers, it receives from them a coating of ink. It next encounters the inking-rollers, to which it delivers this coating. The types next, by the continued revolution of the drum, encounter these inking-rollers, and receive from them a coating of ink, after which they meet the paper-cylinders, upon which they are impressed, and the printing is completed.

Thus in a single revolution of the great central drum the inking-table receives a supply eight times successively from the ductor rollers, and delivers over that supply eight times successively to the inking-rollers, which, in their turn, deliver it eight times successively to the faces of the type, from which it is conveyed finally to the eight sheets of paper held upon the eight cylinders by the tapes.

Let us now explain how the eight cylinders are supplied with paper. Over each of them is erected a sloping desk, *h, h,* &c., upon which a stock of unprinted paper is deposited. Beside this desk stands the 'layer on,' who pushes forward the paper, sheet by sheet, towards the fingers of the machine.

These fingers, seizing upon it, first draw it down in a vertical direction between tapes in the eight vertical frames until its vertical edges correspond with the position of the form of type on the printing cylinder. Arrived at this position its vertical motion is stopped by a self-acting apparatus provided in the machine, and it begins to move horizontally, and it is thus carried towards the printing cylinder by the tapes. As it passes round this cylinder it is impressed upon the type, and printed. It is then carried back horizontally by similar tapes on the other side of the frame, until it arrives at another desk, where the 'taker off' awaits it. The fingers of the machine are there disengaged from it, and the 'taker off' receives it, and disposes it upon the desk. This movement goes on without interruption; the moment that one sheet descends from the hands of the 'layer on,' and being carried vertically downwards begins to move horizontally, space is left for another, which he immediately supplies, and in this manner he delivers to the machine at the average rate of two sheets every five seconds; and the same delivery taking place at each of the eight cylinders, there are 16 sheets delivered and printed every five seconds.

1690



It is found that by this machine in ordinary work between 10,000 and 11,000 per hour can be printed; but with very expert men to deliver the sheets, a still greater speed can be attained. Indeed, the velocity is limited, not by any conditions affecting the machine, but by the power of the men to deliver the sheets to it.

In case of any misdelivery, a sheet is spoiled, and, consequently, the effective performance of the machine is impaired. If, however, a still greater speed of printing were required, the same description of machine, without changing its principle, would be sufficient for the exigency; it would be necessary that the types should be surrounded with a greater number of printing cylinders.

It may be right to observe that these surrounding cylinders and rollers, in the case of 'The Times' machine, are not uniformly distributed round the great central drum; they are so arranged as to leave on one side of that drum an open space equal to the width of the type-form. This is necessary in order to give access to the type-form so as to adjust it.

One of the practical difficulties which Mr. Applegath had to encounter in the solution of the problem, which he has so successfully effected, arose from the shock produced to the machinery by reversing the motion of the horizontal frame, which in the old machine carried the type-form and inking-table, a moving mass which weighed a ton! This frame had a motion of 88 inches in each direction, and it was found that such a weight could not be driven through such a space with safety at a greater rate than about 45 strokes per minute, which limited its *maximum* producing power to 5,000 sheets per hour.

Another difficulty in the construction of this vast piece of machinery was, so to regulate the self-acting mechanism that the impression of the type-form should always be made in the centre of the page, and so that the space upon the paper occupied by the printed matter on one side may coincide exactly with that occupied by the printed matter on the other side.

The type-form fixed on the central drum moves at the rate of 70 inches per second, and the paper is moved in contact with it of course at exactly the same rate. Now, if by any error in the delivery or motion of a sheet of paper, it arrive at the printing cylinder 1–70th part of a second too soon or too late, the relative position of the columns will vary by 1–70th part of 70 inches—that is to say, by 1 inch. In that case the edge of the printed matter on one side would be an inch nearer to the edge of the paper than on the other side. This is an incident which rarely happens, but when it does, a sheet, of course, is spoiled. The waste, however, from that cause is considerably less in the present vertical machine than in the former less powerful horizontal one.

The vertical position of the inking-rollers is more conducive to the goodness of the work—for the type and engraving are only touched on their extreme surface—than the horizontal machine, where the inking-rollers act by gravity; also any dust shaken out of the paper, which formerly was deposited upon the inking-rollers, now falls upon the floor. With this machine 50,000 impressions have been taken without stopping to brush the form or table.

The principle of this vertical-cylinder machine is capable of almost unlimited extension.

An American machine, the invention of R. Hoe and Company, of New York, was a few years ago introduced to this country. Machines of this description were made for 'The Times,' and other newspaper offices, by Mr. Whitworth of Manchester. The following is Mr. Hoe's description of this machine:—

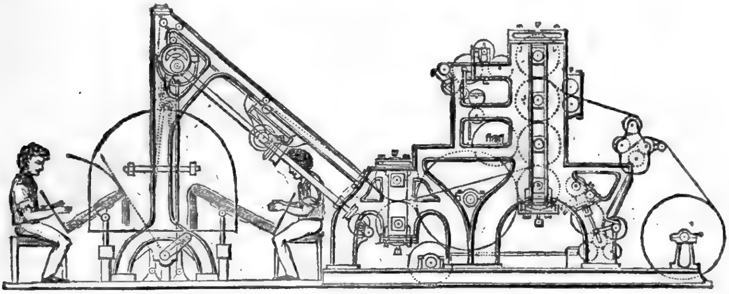
A horizontal cylinder of about 4½ feet in diameter is mounted on a shaft, with appropriate bearings; about one-fourth of the circumference of this cylinder constitutes the bed of the press, which is adapted to receive the form of types—the remainder is used as a cylindrical distributing-table. The diameter of the cylinder is less than that of the form of types, in order that the distributing portion of it may pass the impression-cylinders without touching. The ink is contained in a fountain placed beneath the large cylinder, from which it is taken by a ductor roller, and transferred by a vibrating distributing-roller to the cylindrical distribution-table; the fountain roller receives a slow and continuous rotatory motion, to carry up the ink from the fountain.

The large cylinder being put in motion, the form of types thereon is, in succession, carried to eight corresponding horizontal impression-cylinders, arranged at proper distances around it, which give the impression of eight sheets, introducing one at each impression-cylinder. For each impression-cylinder there are two inked rollers, which vibrate on the distributing surface while taking a supply of ink, and at the proper time pass over the form, when they again fall to the distributing surface. Each page is locked up upon a detached segment of the large cylinder, called by the compositors a 'turtle,' and this constitutes the bed and chase. The column-rules run parallel with the shafts of the cylinder, so as to bind to types near the top. These wedge-shaped column-rules are held down to the bed or 'turtle' by tongues, projecting at intervals along their length, and sliding in rebated grooves cut cross-wise in the face of the bed; the space in the grooves between the column-rules being filled with sliding blocks of metal, accurately fitted, the outer surface level with the surface of the bed, the ends next the column-rules being cut away underneath to receive a projection on the sides of the tongues and screws at the end and side of each page to lock them together, the types are as secure on this cylinder as they can be on the old flat bed.

In 'The Times' office there are two of those machines, one of them being a ten-cylinder machine, which is regularly employed to print 16,000 sheets an hour, and it appears capable of printing 18,000. It is only by means of these two American machines, and two of Applegath's, all working on the different sides of the paper, that the enormous supply required every morning can be produced.

The Walter Press (*fig.* 1691).—In 1862, the circulation of 'The Times' having considerably increased, together with the necessity of issuing quadruple and sextuple sheets, caused the proprietors to increase the power of the machines then in use, and the whole has since been completely superseded by various new productions. The first of these is the Walter Press, brought to maturity in 'The Times' Printing-office, and manufactured on the premises in Printing-House Square. It is almost an original invention; its principal merits being its simplicity, compactness, speed, and economy. It is what is called a 'perfecting machine,' as it prints both sides of the sheet at one revolution. The paper passing through the machine in a direct line, and with mechanical precision, the register will always be perfect; that is to say, the pages on one side are printed exactly on the back of the pages on the other side. The Walter machine occupies a space of only 14 feet by 5 feet, or less than any other machine yet introduced. The speed being altogether independent of manual dexterity, and regulated solely by mechanical appliances, is capable of increase in a way that no other printing machine on any other principle can possibly be. The exclusive use of stereotype-plates releases the type from all wear and tear, so that a fount of type, instead of being renewed every two years, will last at least twenty. The type at present employed in printing 'The Times' has been in use about 15 years. The plates, after being employed for one day's impression, are melted down for the next. The paper mounted on a huge reel, 3 miles 120 yards in length, as it comes from the paper-mill, appears to fly through among the cylinders at the rate of nearly 1,000 feet a minute, and is printed in less than 25 minutes; each reel, when printed, produces 4,350 newspapers. It is led from the reel into a series of small cylinders, where it passes through a trough of cold water, and is then brought between the first and second of four cylinders raised perpendicularly above each other. The top cylinder is encircled by stereotype-casts from four pages of type, and the lowest of the four cylinders is similarly surrounded by stereotype-plates of the remaining four pages of the newspaper. In passing through the first pair of impression-cylinders it is printed on one side. It is next reversed, and passes through the second pair of cylinders, where it is printed on the other side. It then continues its course onwards, passing between two cutting-cylinders, placed in the centre of the machine, which divide the web of the now printed paper into its proper length, forming a complete newspaper. The sheets are then rapidly conducted by tapes into a swing frame, which, as it vibrates, delivers them alternately on either side, and deposits them on tables at which two lads sit to receive them. The sole attendants necessary are those two lads and an overlooker, who places the stereotype-plates on the machine, starts it, and attends to the rolls of paper as they are unwound. The delay in changing from one reel to another scarcely exceeds one minute. The sheets are printed at the rate of 12,000 copies per hour. The machine is almost self-acting, the ink being pumped up into an ink-box from a cistern in the room below. An index is fixed to each machine, which counts each sheet as it is cut. Four, and sometimes five, of these machines are necessary for the printing of 'The Times,' according to the time required for its publication; the whole number being printed in from one hour to one hour and a half. If four machines are required, four stereotype-plates are required from each page. If five machines, five plates of each page, which would be forty plates in the whole. Each page is cast in about twenty minutes.

1691



The following table shows the number of letters in each of the morning newspapers, taken during the month of April 1873:—

Morning Post	632,886	Standard	708,428
Morning Advertiser	684,715	Daily Telegraph	1,053,200
Daily News	704,619	The Times	2,195,963

Platen Machine, or the Spottiswoode Press.—The first successful application of steam, as a motive power, to printing presses with a platen and vertical pressure was made in the office where this book is being printed. Convinced of the superiority of the impression made by flat as compared with that of cylindrical pressure, Mr. Andrew Spottiswoode, assisted by his chief engineer, Mr. Brown, succeeded, after many experiments, in perfecting a machine which combines the excellence of the hand-press with more than four times its speed, and a uniformity in colour which can never be attained by inking by hand. The main point of the invention is the endless screw or drum which takes the carriage and type under the platen, and, after the impression is taken, returns it to its original position.

PRINTING AND NUMBERING CARDS. It will be remembered that in the early days of railway travelling, the ticket system then in vogue at the various stations was a positive nuisance; as every ticket before it was delivered to a passenger had to be stamped and torn out of a book,—thus causing the loss of considerable time to travellers when many passengers were congregated. The first to remedy this was Mr. Edmondson, who constructed an ingenious apparatus for printing the tickets with consecutive numbers, and also dating the same. This gave great facilities for checking the accounts of the station clerks; but owing to the imperfect manner of inking, consequent on the construction of the apparatus, the friction to which the tickets were exposed, before they were delivered up, in a great manner obliterated the printing, and occasionally rendered them quite illegible. By Messrs. Church and Goddard's machine for printing, numbering, cutting, counting, and packing railway tickets, this difficulty is removed, and great speed is attained in manufacturing the tickets, as the several operations are simultaneously performed. Pasteboard cut into strips by means of rollers is fed into the machine, by being laid in a trough, and brought under the prongs of a fork (working with an intermittent movement), which pushes the strips successively forward between the first pair of a series of guide or carrying rollers. There are four pairs of rollers, placed so as to conduct the strip through the machine in a horizontal line; and an intermittent movement is given them for the purpose of carrying the strips forward a short distance at intervals. The standards of the machine carry, at the top, a block termed 'the platen,' as it acts the part of the press-head in the common printing machine,—portions of it projecting downwards between the upper rollers of the first and second, and second and third pairs of carrying rollers, nearly to the horizontal plane, in which the pasteboard lies, so as to sustain it at those points while it receives the pressure of the printing types and numbering discs, hereafter referred to. The types to designate the nature of the ticket, as 'Birmingham, First Class,' are secured in a 'chase,' upon a metal plate or table, which also carries the numbering discs for imprinting the figures upon the cards; and the table by a cam action is alternately raised, to bring the types and numbering discs in contact with the pasteboard, and then lowered into a suitable position, to admit of an inking-roller moving over the types and numbering discs, and applying ink thereto. The table likewise carries at one end a knife, which acts in conjunction with a knife-edge, projecting downwards from the fixed head of the machine, and thereby gives the cross-cut to the strips between the third and fourth pairs of carrying rollers,—thus severing each into a given number of tickets. The strip of pasteboard which is fed into the machine stops on arriving at the second pair of carrying rollers; and, on the ascent of the printing-table, the types print on that portion which is between the first and second pairs of rollers. The strip then passes on to the third pair of rollers, where it stops; and, on the table again ascending, the numbering discs imprint the proper number upon the pasteboard between the second and third pairs; the type, in the meanwhile, printing what is to be the next following ticket. On the next ascent of the table, the strip has advanced to the fourth pair of rollers; and the knives being now brought into contact, the printed and numbered portion of the strip is severed. The now completed ticket is lastly delivered by the fourth pair of rollers into a hollow guide piece, and conducted to a box below, provided with a piston, which, to facilitate the packing of the tickets in the box, can be adjusted to any height to receive the tickets as they fall. To avoid the necessity of having to count the tickets after they are taken from the receiving box, a counting apparatus, connected with the working parts of the machine, is made to strike a bell on the completion of every hundred or more tickets, so as to warn the attendant to remove them from the box. The inking apparatus is assimilated in character to self-acting inkers in ordinary printing presses; and the numbering discs are worked in a manner very similar to those for paging books.

A simple arrangement of apparatus for printing and numbering cards has been introduced by Messrs. Harrild and Sons. The types are fixed in a metal frame, which also carries the numbering discs. This frame is mounted on a rocking shaft, and is furnished with a handle, whereby it is rocked to bring down the types and discs upon the card, to produce the impression. When the frame is raised again, the units disc is moved forward one figure, and the types are inked by a small roller, which takes its supply of ink from an inking-table, that forms the top of the frame.

M. Baranowski, of Paris, invented a machine for printing and numbering tickets, and also indicating the number printed. The types and numbering discs are carried by a horizontal rotating shaft, upon which, near each end thereof, is a metal disc; and upon the periphery of these discs a metal frame is affixed, which carries the types and numbering discs, and corresponds in curvature with the edge of the discs. The types for printing the inscription upon the ticket are arranged at right angles to the length of the shaft, which position admits of some lines of the inscription being printed in one colour, and the remainder in another colour. In the type-frame a slot or opening is formed lengthwise of the shaft; and behind this opening are three numbering discs, and three discs for indicating the quantity of tickets numbered,—all standing in the same row. The numbering discs are made with raised figures, which project through the slot, in order to print the number upon the ticket; and on the peripheries of the registering discs (which move simultaneously with their corresponding numbering discs), the figures are engraved. The tickets to be printed and numbered are placed in a rectangular box or receiver, having at the bottom a flat sliding piece, which has a reciprocating motion for the purpose of pushing the lowest ticket out of the box, through an opening in the front side thereof, beneath an elastic pressing-roller of india-rubber; the type-frame (with the types and figures properly inked), is at the same time brought, by the rotation of its shaft, into contact with the ticket beneath the pressing roller, and as it continues its motion, it causes the ticket to move forward beneath the pressing roller, and to be properly printed and numbered. The ticket then falls from the machine; and the type-frame, carried on by the revolution of the shaft, brings that number on the registering discs which corresponds with the number printed on the ticket, under a small opening in the case, covered with glass; whereby the number of tickets printed will be indicated.

PRINTING, NATURE. See Nature Printing.

PRINTING ROLLERS. Elastic inking-rollers were introduced by Messrs. Donkin and Bacon. They are made of a mixture of glue and treacle, or of glue and honey; the American honey, it is said, being preferred. 1 pound of good glue is softened by soaking in cold water for twelve hours, and then it is united, by means of heat, with about two pounds of ordinary treacle. See Printing.

Messrs. Hoe & Co. give the following directions for making and preserving composition-rollers: For *cylinder-press rollers*, Cooper's No. 1. × glue is sufficient for ordinary purposes, and will be found to make as durable rollers as higher-priced glues:—

Place the glue in a bucket or pan, and cover it with water; let it stand half an hour, or until about half penetrated with water (care should be used not to let it soak too long), then pour it off, and let it remain until it is soft. Put it in the kettle and cook it until it is thoroughly melted. If too thick, add a little water until it becomes of proper consistency. The molasses may then be added, and well mixed with the glue by frequent stirring. When properly prepared, the composition does not require boiling more than an hour. Too much boiling candies the molasses, and the roller consequently will be found to lose its suction much sooner. In proportioning the material, much depends upon the weather and temperature of the place in which the rollers are to be used. 8 pounds of glue to 1 gallon of sugar-house molasses, or syrup, is a very good proportion for summer, and 4 pounds of glue to 1 gallon of molasses for winter use.

Hand-press rollers may be made of Cooper's No. 1¼ (one and a quarter) glue, using more molasses, as they are not subject to so much hard usage as *cylinder-press rollers*, and do not require to be as strong; for the more molasses that can be used the better is the roller. Before pouring a roller, the mould should be perfectly clean, and well oiled with a swab, but not to excess.

Rollers should not be washed immediately after use, but should be put away with the ink on them, as it protects the surface from the action of the air. When washed and exposed to the atmosphere for any length of time, they become dry and skinny. They should be washed about half an hour before using them. In cleaning a *new* roller, a little oil rubbed over it will loosen the ink, and it should be scraped clean with the back of a case-knife. It should be cleaned in this way for about one week, when *lye* may be used. New rollers are often spoiled by washing them too soon with lye. Camphene may be substituted for oil; but owing to its combustible nature it is objectionable, as accidents may arise from its use.

PRINTING, STEREOTYPE. See Stereotype.

PROOF SPIRIT. See Alcohol.

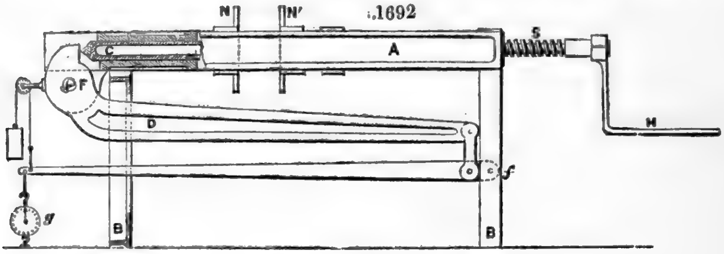
PROPYLENE. A gas obtained among the products of the decomposition of amylic alcohol. See Gas-Coal.

PROTEINE. The name given to the substance obtained by digesting albuminous matters in weak caustic potash, and precipitating by acetic acid.

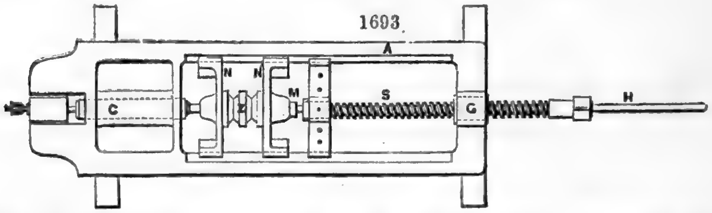
PROTOGINE (*πρῶτος*, first; *γίγνομαι*, to form). A granite composed of felspar, quartz, and talc. This term is nearly restricted to the French geologists.

PROUSTITE, or *Light Red Silver Ore.* An arsenio-sulphide of silver, resembling pyrargyrite, but distinguished by its paler cochineal-red colour. It is a valuable ore, found in Saxony, Mexico, Chili, Nevada, &c. See Silver.

PROVING MACHINE. The figures show a useful machine for testing the quality and power of india-rubber springs, designed by Mr. George Spencer, of the firm of Geo. Spencer and Co., and used by them for that purpose. *Fig.* 1692 shows an elevation, partly in section, of the machine: *fig.* 1693 a plan of the same. A is a strong cast-iron frame, supported by two cast-iron standards, B, B; C is a sliding piston, working in a hole cast in the end of frame, A, one end of which impinges against the short arm of a strong cast-iron lever, D, forming one of a system of compound levers as shown, having fulcrums at F and *f*, and provided with a Salter's balance, *g*, to register the power exerted by the spring.



1692



1693

At the other end of frame, A, a brass nut, G, is placed in a hole in the frame, through which a square-threaded screw, S, works by means of the handle, H, or by a long lever of wrought iron, according to the power of spring to be tested.

The spring to be tested is placed between the two sliding guide-plates, N, N′, and a wrought-iron bolt passed through the plates, N, N′, and spring, Z, and passing into the hollow piston, C, for the purpose of keeping the spring in correct position, and receiving in its hollow head, M, the end of the screw, S. The action may be thus described:—The handle, H, being turned, the screw, S, advances and pushes on the plate N′, by means of the bolt-head, M. The other plate, N, rests against the piston, C, and is pressed against it by the intervening spring, Z. The leverage, D, is so arranged that 1 lb. on the dial is equal to 2 cwts. on the spring, or, in other words, is 1 in 224. Springs of a force of 20 tons can be tested by this machine safely. See Caoutchouc.

PROVISIONS, CURING OF. See Meats, Preserved; Putrefaction.

PRUNELLA. A thin woollen or mixed stuff now chiefly used for covering shoes, especially such as are worn by old women.

PRUNUS. A genus of the *Rosaceæ*, containing several species which yield edible fruits. The varieties of *P. domestica* are known as plums, greengages, and damsons. *P. cerasus* is the cherry; *P. Armeniaca* the apricot; and *P. spinosa* the sloe or blackthorn.

PRUSSIAN BLUE. (*Berliner Blau*, Ger.) This is, in its pure state, a ferrocyanide of iron (ferric-ferrocyanide). When organic matters abounding in nitrogen, such as dried blood, horns, hair, skins, or hoofs of animals, are triturated along with potash in a strongly-ignited iron pot, a dark grey mass is obtained, that affords to water the liquor originally called *lixivium sanguinis*, or blood-lye. This solution yields crystals, known in commerce as the yellow prussiate of potash. If to this salt solutions of any per-salt of iron be added, Prussian blue is formed. If the iron in the salt employed be present as protoxide, it will afford a precipitate, at first pale blue, which turns dark blue in the air. If, however, the salt employed contains peroxide of iron (ferric salts) the precipitate is at once a dark blue. The white cyanide of iron (the prussiate of the pure protoxide) when exposed to the air in a moist condition, becomes, as above stated, dark blue; yet the new combination formed in this case through absorption of oxygen, is essentially different from that resulting from the precipitation by the peroxide of iron, since it contains an excess of the peroxide in addition to the usual two cyanides of iron. It has been therefore called *basic* Prussian blue, and, from its dissolving in pure water, *soluble* Prussian blue.

Both kinds of Prussian blue agree in being void of taste and smell, in attracting humidity from the air when they are artificially dried, and being decomposed at a heat above 348° Fahr. The neutral or insoluble Prussian blue is not affected by alcohol; the basic, when dissolved in water, is not precipitated by that liquid. Neither is it acted upon by dilute acids; but they form with concentrated sulphuric acid a white pasty mass, from which they are again reproduced by the action of cold water. They are decomposed by strong sulphuric acid at a boiling-heat, and by strong nitric acid at common temperatures; but they are hardly affected by the muriatic. They become green with chlorine, but resume their blue colour when treated with deoxidising reagents. When Prussian blue is digested in warm water along with potash, soda, or lime, peroxide of iron is separated, and a ferroprussiate of potash, soda, or lime remains in solution.

The precipitation of Prussian blue.—Green sulphate of iron is commonly employed by the manufacturer, on account of its cheapness, for mixing with solution of the ferroprussiate, in forming Prussian blue, though the persulphate, nitrate, or muriate of iron would afford a much richer blue pigment. Whatever salt of iron be preferred, it should be carefully freed from any cupreous impregnation, as this would give the pure blue a dirty brownish cast. The green sulphate of iron is the most advantageous precipitant, on account of its affording protoxide, to convert into ferrocyanide any cyanide of potassium that may happen to be present in the uncrystallised lixivium. The carbonate of potash in that lixivium might be saturated with sulphuric acid before adding the solution of sulphate of iron; but it is more commonly done by adding a certain portion of alum, in which case alumina falls along with the Prussian blue; and though it renders it somewhat paler, yet it proportionally increases its weight; whilst the acid of the alum saturates the carbonate of potash, and prevents its throwing down iron-oxide, to degrade by its brown-red tint the tone of the blue. For every pound of pearlash used in the calcination, from two to three pounds of alum are employed in the precipitation. When a rich blue is wished for, the free alkali in the Prussian lye may be partly saturated with sulphuric acid, before adding the mingled solutions of copperas and alum. One part of the sulphate of iron is generally allowed for 15 or 20 parts of dried blood, and 2 or 3 of horn-shavings or hoofs. But the proportion will depend very much upon the manipulations; which, if skilfully conducted, will produce more of the cyanides of iron, and require more copperas to neutralise them. The mixed solutions of alum and copperas should be progressively added to the lye as long as they produce any precipitate. This is not at first a fine blue, but a greenish grey, in consequence of the admixture of some white cyanide of iron; it becomes gradually blue by the absorption of oxygen from the air, which is favoured by agitation of the liquor. Whenever the colour seems to be as beautiful as it is likely to become, the liquor is to be run off by a spigot or cock from the bottom of the precipitation vats, into flat cisterns, to settle. The clear supernatant fluid, which is chiefly a solution of sulphate of potash, is then drawn off by a syphon; more water is run on with agitation to wash it, which after settling is again drawn off; and whenever the washings become tasteless, the sediment is thrown upon filter sieves, and exposed to dry, first in the air of a stove, but finally upon slabs of chalk or Paris-plaster. But for several purposes, Prussian blue may be best employed in the fresh pasty state, as it then spreads more evenly over paper and other surfaces.

A good article is known by the following tests:—It feels light in the hand, adheres to the tongue, has a dark lively blue colour, and gives a smooth deep trace; it should not effervesce with acids, as when adulterated with chalk; nor become pasty with boiling water, as when adulterated with starch. The Paris blue, prepared without alum, with a peroxide salt of iron, displays, when rubbed, a copper-red lustre, like indigo. Prussian blue, degraded in its colour by an admixture of free oxide of iron, may be improved by digestion in dilute sulphuric or muriatic acid, washing, and drying.

Its relative richness in the real ferroprussiate of iron may be estimated by the quantity of potash or soda which a given quantity of it requires to destroy its blue colour.

Sulphuretted hydrogen passed through Prussian blue diffused in water whitens it; while prussic acid is eliminated, sulphur is thrown down, and the sesquicyanide of iron is converted into the single cyanide. Iron and tin operate in the same way. When Prussian blue is made with two atoms of ferrocyanide of potassium instead of one, it becomes soluble in water. Soluble Prussian blue is generally prepared by adding perchloride of iron to excess of ferrocyanide of potassium.

For the mode of applying this pigment in dyeing, see Calico-Printing.

A process for Prussian blue, which deserves notice, as the first in which that interesting compound was made to any extent independently of animal-matter, was introduced by Mr. Lewis Thompson, who received a medal from the Society of Arts, in 1837, for this invention. He observed that in the common way of manufacturing prussiate of potash, the quantity of nitrogen furnished by a given weight of animal-matter is not large, and seldom exceeds 8 per cent.; and of this small quantity, at least one half appears to be dissipated during the ignition. It occurred to him that the atmosphere might be economically made to supply the requisite nitrogen, if caused to act in favourable circumstances upon a mixture of carbon and potash. He found the following to answer:—Take of pearlash and coke, each 2 parts; iron turnings, 1 part; grind them together into a coarse powder; place this in an open crucible, and expose the whole for half an hour to a full red heat in an open fire, with occasional stirring of the mixture. During this process, little jets of purple flame will be observed to rise from the surface of the materials. When these cease, the crucible must be removed and allowed to cool. The mass is to be lixiviated; the lixivium, which is a solution of ferrocyanide of potassium, with excess of potash, is to be treated in the usual way, and the black matter set aside for a fresh operation, with a fresh dose of pearlash. Mr. Thompson stated that one pound of pearlash, containing 45 per cent. of alkali, yielded 1,355 grains of pure Prussian blue, or ferrocyanide of iron, or about 3 ounces avoirdupois.

Of late years several improvements have been introduced into the manufacture of Prussian blue, relating chiefly to oxidation of the white precipitate thrown down from a solution of green sulphate of iron and alum by means of yellow prussiate of potash. Instead of oxidising this precipitate by exposure to the atmosphere, recourse may be had to the oxidising power of chlorine; thus nitro-muriatic acid (aqua regia) may be added to the precipitate. Perchloride of iron or perchloride of manganese may be used with similar effect.

Prussian blue may also be prepared from the ammoniacal liquor of gas-works, or from the spent lime of gas-purifiers.

PRUSSIAN BROWN. A fine deep brown colour obtained by adding the yellow prussiate of potash (ferrocyanide of potassium) to a solution of sulphate of copper.

PRUSSIATE OF POTASH. See Potash, Prussiate of.

PRUSSIC ACID. See Hydrocyanic Acid.

PSILOMELANE. An ore of Manganese, which see.

PUDDLING OF IRON. See Iron.

PUFF PASTE. A preparation of flour and butter, which is in great demand, not only at the pastry-cooks', but in almost every private family. Take a certain quantity of flour, say half a pound, put it upon a wooden board, make a hole or depression in the centre, and mix it with somewhat less than half a pint of cold water, so as to make a softish paste; dry it off from the board by shaking a little flour over and under, as is well known, but do not 'work it' more than you can help. Take now a quarter of a pound of fresh butter, which should be *as hard as possible* (and therefore it should be kept in as *cold* a place as practicable, the ice closet, if procurable, being the best place), and squeeze out all the water, or butter-milk which it contains, by kneading it with one hand on the board. This operation is called in French '*manier le beurre.*' Roll now the paste prepared as above into a flat, thick, square slab, extending about 6 or 7 inches; lay the pat of butter, treated as above, in the middle of the slab of paste, and so wrap the butter up into it by folding the sides of the paste all round over it; roll the whole mass gently with the rolling-pin, so as to form a thick sheet, put it upon a tin plate, or tray, cover it with a linen cloth wetted with water as cold as possible, and leave the whole at rest for about a quarter of an hour in a cold place. At the end of that time, roll the mass with the rolling-pin into a sheet about 15 or 16 inches long, and fold it into three, one over the other; roll it out again into a sheet as before, and again fold it into three, one over the other, as before, and repeat this operation once more, making three times in all. Put the square mass, with a wet cloth upon it, in a cold place for another quarter of an hour, as before, and at the end of that time roll it out with the rolling-pin, and fold it into three, one over the other, as above; and do this once more, making five times in all, after which the paste is ready for use. Care must be taken, during the rolling, continually to dust the board and the paste with a little flour, to prevent sticking. The paste may now be placed in the dish, or tin, in which it is to be baked, taking care to cut the protruding edges with a pointed and sharp knife, so as to leave the paste all round with a clean cut edge, for otherwise *it will not puff up or swell.* The thick edges of pies and tarts are made by cutting strips of the paste with the knife, and carefully laying them on all round, taking *care to leave the edges quite sharp.* The prepared articles are then put in an oven, previously brought to a good heat, and the elastic vapour disengaged from the butter and water will at once cause the paste to swell into parallel layers of great tenacity, and *apparently* light, but really very heavy, since each of these thin laminæ is compact and distinct. It is essential to the success of the operation that the floor of the oven should be hot.

PUMICE-STONE (*Pierre-ponce*, Fr.; *Bimstein*, Ger.) is a spongy, vitreous-looking mineral, consisting of fibres of a silky lustre, interlaced with each other in all directions. It floats upon water, is harsh to the touch, having in mass a mean sp. gr. of 0·914; though brittle, it is hard enough to scratch glass and most metals. Its colour is usually greyish white; but it is sometimes bluish, greenish, reddish, or brownish. It fuses without addition at the blowpipe into a white enamel. According to Klaproth, it is composed of silica, 77·5; alumina, 17·5; oxide of iron, 2; potassa and soda, 3; in 100 parts. The acids have hardly any action upon pumice-stone. The chief localities of pumice are, the Islands of Lipari, Ponza, Ischia, Vulcano, Andernach, upon the banks of the Rhine; in Teneriffe, Iceland, and Auvergne, &c.

PUMP. See Hydraulic Machinery.

PURBECK MARBLE. A hard bluish-grey limestone, so called from its being found in the Isle of Purbeck, where it occurs in the upper beds of the formation of that name. Like the Sussex marble, it is susceptible of a fine polish, and is crowded with the remains of a species of freshwater snail (*Paludina carinifera*), and the beauty of the marble is the result of the pattern produced by the sections of the included shells. These latter are of a much smaller species than those which occur in the Sussex marble, and the difference in the size of the shells affords an easy means of distinguishing between the two marbles.

Many old sepulchral monuments are partly composed of Purbeck marble; as are also the slender shafts and columns of many of the Gothic churches of this country, of which there are examples in the Temple Church in London, Westminster Abbey, Winchester and Salisbury Cathedrals, &c.

Fine blocks of this marble are still quarried in the Isle of Purbeck, but, except for ecclesiastical purposes, it is little used, in consequence probably of its inferiority to other marbles with regard to colour.—H. W. B.

PURPLE OF CASSIUS, *Gold purple* (*Pourpre de Cassius*, Fr.; *Goldpurpur*, Ger.). See Cassius, Purple of.

PURPLE OF MOLLUSCA. A viscid fluid, secreted by the *Buccinum lapillus*, and some other shell-fish. The Tyrian dye of the Greeks, and Imperial Purple of the Romans, was in all probability obtained from the same source,—the mollusca of the Mediterranean Sea. See Murexide.

PURPLE DYES. The purple dyes now obtained by more or less complex processes from coal-tar are so incomparably superior to any others, both in brilliancy and permanence, that their production has opened up a new era in dyeing and calico-printing. See Aniline, &c.

PURPURIC ACID is an acid obtained by treating uric or lithic acid with dilute nitric acid. It has a fine purple colour. See Murexide.

PURPURIN is the name of a colouring principle, supposed by Robiquet and Colin to exist in madder. See Madder.

PURREE. A yellow colouring-matter, imported into Europe from India and China. It is said to be formed from the urine of camels, elephants, and buffaloes, after the animals have eaten the fruit of the mangosteen. Stenhouse, however, believes it to be a vegetable extract mixed with magnesia. It is much used in the manufacture of Indian yellow, which is employed in oil and water-colour painting.

PUTREFACTION, *and its Prevention.* (*Fäulniss*, Ger.) Putrefaction is the spontaneous decomposition of albuminoid or protein and gelatine compounds, when exposed to a limited amount of air. It is the decomposition of bodies containing nitrogen, called by some persons azotised bodies, although they are produced only by life, are the principal means of producing life, and more fitly called *zoogens.*

Conditions of the Prevention of Putrefaction. The circumstances by which putrefaction is counteracted, are: 1, the chemical change of the azotised juices; 2, the abstraction of water; 3, the lowering of the temperature; and 4, the exclusion of oxygen. The methods actually in use may be called salting, smoking, drying, exclusion of air, and parboiling.

1. *The chemical changes of the azotised juices.*—The substance which in dead animal-matter is first attacked with putridity, and which serves to communicate it to the solid fibrous parts, is albumen, as it exists combined with more or less water in all the animal fluids and soft parts. In those vegetables also which putrefy, it is the albumen probably which first suffers decomposition; and hence those plants which contain most of that proximate principle are most apt to become putrid, and most resemble in this respect animal substances. The albumen when dissolved in water, very readily putrefies in a moderately warm air; but when coagulated, it seems as little liable to putridity as fibrin itself. By this change it throws off the superfluous water, becomes solid, and may then be easily dried. Hence those means which by coagulation make the albumen insoluble, or form with it a new compound, which does not dissolve in water, but which resists putrefaction, are powerful antiseptics. Whenever the albumen is coagulated, the uncombined water may be easily evaporated, and the residuary solid matter may be readily dried in the air, so as to be rendered unsusceptible of decomposition.

Some acids combine with the albumen, without separating its solution; such is the effect of vinegar, citric acid, tartaric acid, &c.

Tannin combines with the albuminous and gelatinous parts of animals, and forms insoluble compounds, which resist putrefaction; on which fact the art of tanning is founded.

Alcohol, oil of turpentine, and some other volatile oils, likewise coagulate albumen, and thereby protect it from putrescence. The most remarkable operation of this kind is exhibited by wood-vinegar, chiefly in consequence of the *creasote* contained in it, according to the discovery of Reichenbach. This peculiar substance has so decided a power of coagulating albumen, that even the minute portion of it present in pyroligneous vinegar assists in preserving animal parts from putrefaction, when they are simply soaked in it. Thus, also, flesh is cured by wood-smoke. Distilled wood-tar likewise protects animal-matter from change, by the creasote it contains. The pyroligneous acid was said to contain five per cent. of creasote; it does not do so now.

The metallic salts operate yet more effectually as antiseptics, because they form with albumen still more intimate combinations. Under this head we class the green and red sulphates of iron, chloride of zinc, the acetate of lead, and corrosive sublimate; the latter, however, from its poisonous qualities, can be employed only on special occasions. Nitrate of silver, though equally noxious to life, is so antiseptic that a solution containing only $\frac{1}{500}$th of the salt is capable of preserving animal-matter from corruption.

2. *Abstraction of water.*—Even in those cases where no separation of the albumen takes place in a coagulated form, or as a solid precipitate, by the operation of a substance foreign to the animal juices, putrefaction cannot go on, any more than other kinds of fermentation, in bodies wholly or in a great measure deprived of their water, as the albumen itself runs much more slowly into putrefaction, when less water is contained in it; and in the desiccated state it is as little susceptible of alteration as any other dry vegetable- or animal-matter. Hence, the proper drying of an animal substance becomes a universal preventive of putrescence. In this way fruits, herbs, cabbages, fish, and flesh may be preserved from corruption. If the air be not cold and dry enough to cause the evaporation of the fluids before putrescence begins, the organic substance must be dried by artificial means, such as by being exposed in thin slices in properly-constructed air-stoves. At a temperature under 140° F., the albumen dries up without coagulation, and may then be redissolved in cold water, with its valuable properties unaltered. Mere desiccation, indeed, can hardly ever be employed upon flesh. Culinary salt is generally had recourse to, either alone or with the addition of saltpetre or sugar. These alkaline salts abstract water in their solution, and, consequently, concentrate the aqueous solution of the albumen; whence, by converting the simple watery fluid into salt water, which is in general less favourable to the fermentation of animal-matter than pure water, and by expelling the air, and probably by chemical combinations, they counteract putridity. On this account salted meat may be dried in the air much more speedily and safely than fresh meat. The drying is promoted by heating the meat merely to such a degree as to consolidate the albumen, and eliminate the superfluous water.

3. *Defect of warmth.*—As a certain degree of heat is requisite for the vinous fermentation, so is it for the putrefactive. If in a damp atmosphere, or in one saturated with moisture, if the temperature stand at from 70° to 80° F., the putrefaction goes on most rapidly; but it proceeds languidly at a few degrees above freezing, and is suspended altogether at that point. The mammoths found in the Siberian ice are proofs of the preservative influence of low temperature. In temperate climates, ice-houses serve the purpose of keeping meat fresh and sweet for any length of time.

4. *Abstraction of oxygen gas.*—As the putrefactive decomposition of a body first commences with the absorption of oxygen from the atmosphere, so it may be retarded by the exclusion of this gas. It is not, however, enough to remove the aerial oxygen from the surface of the body, but we must expel all the oxygen that may be diffused among the vessels and other solids, as this portion suffices in general to excite putrefaction, if other circumstances be favourable. The expulsion is most readily accomplished by a boiling or lower heat, which, by expanding the air, evolves it in a great measure. Milk, soup, solution of gelatine, &c., may be kept long in a fresh state, if they be subjected in an air-tight vessel every other day to a boiling heat. Oxygenation may be prevented in several ways: by burning sulphur or phosphorus in the air of the meat receiver; by filling this with compressed carbonic acid; or with oils, fats, syrups, &c., and then sealing it hermetically. Charcoal-powder recently calcined is efficacious in preserving meat, as it not only excludes air from the bodies surrounded by it, but intercepts the oxygen by condensing it, and causing it to combine with putrefying substances. When butchers' meat is enclosed in a vessel filled with sulphurous acid, it absorbs the gas, and remains for a considerable time proof against corruption. The same result is obtained if the vessel be filled with ammoniacal gas. At the end of 76 days such meat has still a fresh look, and may be safely dried in the atmosphere.

Peculiar Antiseptic Processes.—Upon the preceding principles and experiments depend the several processes employed for protecting substances from putrescence and corruption. Here we must distinguish between those bodies which may be preserved by any media suitable to the purpose, as anatomical preparations or objects of natural history, and those bodies which, being intended for food, can be cured only by wholesome and agreeable means.

Preservation of specimens of animals, &c.—Many methods have been planned to preserve animals: all of them dependent on substances mentioned under DISINFECTANTS. Charles Waterton used corrosive sublimate dissolved in alcohol. The skin of the animal being separated, is dipped into the solution and dried. The inside of the animal is always removed, the bones scraped clean and dipped, the feathers or hairs touched by the solution, or the whole immersed in it. Sometimes alcohol of 60 to 70 per cent. is used, or alcohol of 30 per cent. with creasote dissolved in it. Sulphurous acid will not suit when there are colours, but sulphites of the alkalis have been injected into the veins and arteries with good result; as also sulphurous acid and creasote. Peron preserved fishes for specimens on shipboard by floating them in an alcoholic liquor by corks, thus preventing them from being pressed. He first washed them in sea-water, vinegar, and camphor spirits: he corked the vessels with tallowed corks. Dufresne wrapped each in a cloth with tow between the specimens, and all in alcoholic liquids. Louis Vernet used arsenic, 1 lb. in 40 gallons of water. Sulphate of zinc was proposed for embalming by Comte de Fontainemoreau, sometimes adding alcohol. Wood is preserved by Kyan's process, corrosive sublimate being used; also by Bethel's process, the use of heavy oil of tar; and manures are preserved by carbolates by MacDougall. Injection of the arteries and veins by chloride of zinc, chloride of arsenic, and chloride of aluminium, sulphate of zinc, and sulphates, corrosive sublimate, &c., have all been tried, and are more or less satisfactory. Peppers and spices of all kinds have been used in stuffing and embalming, and may all be made to act when care is employed and abundance used. Girolamo Segato dried bodies so hard that he made a table of 214 pieces of human flesh from different parts of the body. He is said also to have made members preserve their elasticity for an indefinite time. Some remarkable specimens of this kind are said to exist, and have received the honour of sanctity. Waterton made skins preserve their flexibility for some days by the use of corrosive sublimate and slow drying. Dr. Ure says, 'for preserving animal bodies in an embalmed form, mummy-like, a solution of chloride of mercury and wood-vinegar is most efficacious. As there is danger in manipulating with that mercurial salt, and as in the present state of our knowledge of creasote, we have it in our power to make a suitable strong solution of this substance in vinegar or spirit of wine, I am led to suppose that it will become the basis of most antiseptic preparations for the future.'

CURING OF PROVISIONS.

Flesh, &c.—The ordinary means employed for preserving butchers' meat are, drying, smoking, salting, and pickling or souring.

Drying.—The best mode of operating is as follows:—The flesh must be cut into slices from 2 to 6 ounces in weight, immersed in boiling water for five or six minutes, and then laid on open trellis-work in a drying-stove, at a temperature kept steadily about 122° F., with a constant stream of warm dry air. That the boiling water may not dissipate the soluble animal-matters, very little of it should be used, just enough for the meat to be immersed by portions in succession, whereby it will speedily become a rich soup, fresh water being added only as evaporation takes place. It is advantageous to add a little salt, and some spices, especially coriander-seed, to the water. After the parboiling of the flesh has been completed, the soup should be evaporated to a gelatinous consistence, in order to fit it for forming a varnish to the meat after it is dried, which may be completely effected within two days in the oven. By this process two-thirds of the weight is lost. The perfectly dry flesh must be plunged, piece by piece, in the fatty gelatinous matter liquefied by a gentle heat; then placed once more in the stove, to dry the layer of varnish. This operation may be repeated two or three times, in order to render the coat sufficiently uniform and thick. Butchers' meat dried in this way keeps for a year, affords, when cooked, a dish similar to that of fresh meat, and is therefore much preferable to salted provisions. The drying may be facilitated, so that larger lumps of flesh may be used, if they be imbued with some common salt immediately after the parboiling process, by stratifying them with salt, and leaving them in a proper pickling tub for 12 hours before they are transferred to the stove. The first method, however, affords the more agreeable article.

Baron Cha. Wetterstedt enclosed meat in corn- or potato-flour, then dried it on shelves at 120° F. Graefer, in 1780, parboiled and then dried. Some have proposed to hang the substances up and to allow no air to approach without passing it first through chloride of calcium to dry it. Milk was formerly preserved by drying to a powder.

Smoking.—This process consists in exposing meat previously salted, or merely rubbed over with salt, to wood-smoke in an apartment so distant from the fire as not to be unduly heated by it, and into which the smoke is admitted by flues at the bottom of the side walls. Here the meat combines with the empyreumatic acid of the smoke, and gets dried at the same time. The quality of the wood has an influence upon the smell and taste of the smoke-dried meat; smoke from beech wood and oak being preferable to that from fir and larch. Smoke from the twigs and berries of juniper, from rosemary, peppermint, &c., imparts somewhat of the aromatic flavour of these plants. A slow smoking with a slender fire is preferable to a rapid and powerful one, as it allows the empyreumatic principles time to penetrate into the interior substance, without drying the outside too much. To prevent soot from attaching itself to the provisions, they may be wrapped in cloth, or rubbed over with bran, which may be easily removed at the end of the operation.

The process of smoking depends upon the action of the wood-acid, or the creasote volatilised with it, which operates upon the flesh. The same change may be produced in a much shorter time by immersing the meat for a few hours in pyroligneous acid, then hanging it out in a dry air, which, though moderately warm, makes it fit for keeping, without any taint of putrescence. After a few days' exposure, it loses the empyreumatic smell, and then resembles thoroughly-smoked provisions. The meat dried in this way is in general somewhat harder than by the application of smoke, and therefore softens less when cooked, a difference to be ascribed to the more sudden and concentrated operation of the wood vinegar, which effects in a few hours what would require smoking for several weeks.

Salting.—The meat should be rubbed well with common salt, containing about one-sixteenth of saltpetre, and one thirty-secondth of sugar, till every crevice has been impregnated with it; then sprinkled over with salt, laid down for 24 or 48 hours, and, lastly, subjected to pressure. It must next be sprinkled anew with salt, packed into proper vessels, and covered with the brine obtained in the act of pressing, rendered stronger by boiling down. For household purposes it is sufficient to rub the meat well with good salt, to put it into vessels, and load it with heavy weights, in order to squeeze out as much pickle as will cover its surface. If this cannot be had, a pickle must be poured on it, composed of 4 pounds of salt, 1 pound of sugar, and 2 ozs. of saltpetre dissolved in 2 gallons of water.

Mr. Fitch patented the use of a liquid containing 2 cwts. of common salt to the product of distillation of 2 cwts. of wood, adding sugar, treacle, and saltpetre. Some people drive the salt in by force of pressure, some by centrifugal motion.

Milk has been preserved by the use of carbonate of soda, preventing acidity. Alum has been patented, for shellfish especially. See MILK, CONDENSED.

E. Masson injects the veins and arteries of carcases with a solution containing 10½ oz. of common salt and 3½ of nitre in 2¼ pints of water. D. R. Long injects antiputrescent and flavouring substances, such as salt, saltpetre, spices, and vinegar. J. Murdoch injected chloride of aluminium, a very powerful agent, common salt, and nitre. Brooman communicated a proposal to use, first, sulphurous gas, and then coat thick with a substance keeping out the air. Chloride of lime has also been used in chambers holding meat, and sulphur has been burnt and nitrous gas has been evolved in similar places.

Preserving with vinegar, sugar, &c.—Vinegar dissolves or coagulates the albumen of flesh, and thereby counteracts its putrescence. The meat should be washed, dried, and then laid in strong vinegar. Or it may be boiled in the vinegar, allowed to cool in it, and then set aside in a cold cellar, where it will keep sound for several months.

Fresh meat may be kept for some months in water deprived of its air. If we strew on the bottom of a vessel a mixture of iron-filings and flowers of sulphur, and pour over them some water which has been boiled, so as to expel its air, meat immersed in it will keep a long time, if the water be covered with a layer of oil, from half an inch to an inch thick. Meat will also keep fresh for a considerable period when surrounded with oil, or fat of any kind, so purified as not to turn rancid of itself especially if the meat be previously boiled. This process is called 'potting.'

Eggs.—These ought to be taken new laid. The essential point towards their preservation is the exclusion of the atmospheric oxygen, as their shells are porous, and permit the external air to pass inwards, and to excite putrefaction in the albumen. There is also some oxygen always in the air-cell of the eggs, which ought to be expelled or rendered inoperative, which may be done by plunging them for 5 minutes in water heated to 140° F. The eggs must then be taken out, wiped dry, besmeared with some oil (not apt to turn rancid) or other unctuous matter, packed into a vessel with their narrow ends uppermost, and covered with sawdust, fine sand, or powdered charcoal. Eggs coated with gum arabic and packed in charcoal will keep fresh for a year. Lime-water, or rather milk of lime, is an excellent vehicle for keeping eggs in. Some persons coagulate the albumen partially, and also expel the air by boiling the eggs for two minutes, and find the method successful. When eggs are intended for hatching, they should be kept in a cool cellar. Eggs exposed, in the holes of perforated shelves, to a constant current of air lose about ¾ of a grain of their weight daily, and become concentrated in the albuminous part, so as to be little liable to putrefy. Each egg requires a hole in the shelf for itself. For long sea voyages, the surest means of preserving eggs is to dry up the albumen and yolk by first triturating them into a homogeneous paste, then evaporating this in an air-stove or a water-bath heated to 125°, and putting up the dried mass in vessels which may be made air-tight. When used, it should be dissolved in 3 parts of cold or tepid water.

The excellent process for preserving all kinds of butchers' meat, fish, and poultry, first contrived by M. Appert is described in the article MEATS, PRESERVED. That article also contains a description of the methods now practised for the preservation of Australian meat, which at the present time is largely imported into this country.

PUTTY POWDER. Binoxide of tin, obtained by treating metallic tin with nitric acid, when the metal is converted into hydrated metastannic acid, and this when heated becomes anhydrous. In this state it is known as *putty powder*, and is employed as a polishing agent; it is also used to impart an opaque white colour to enamels and dial-plates.

PYRARGYRITE, or *Dark-red Silver-ore.* An antimonio-sulphide of silver, forming a valuable ore at Andreasberg in the Hartz, in Mexico, and in Chile. See SILVER.

PYRETHRUM. A genus of plants belonging to the natural order *Compositæ.* It contains the feverfew and the pellitory of Spain.

PYRIDINE, $C^{10}H^5N$ ($\mathbf{C^5H^5N}$). A volatile base homologous with picoline, lutidine, collidine, and parvoline. It was discovered by Anderson in bone-oil. It is also contained in Dorset shale, naphtha, coal-naphtha, and in crude chinoline.

PYRITES. A term originally applied to yellow sulphide of iron, because it struck fire with steel. It is in strictness still confined to this mineral; but where sulphur exists in combination with copper, cobalt, or nickel, these minerals also are called pyrites.

1. *Iron Pyrites, Mundic; Schwefelkies, Eisenkies.*—This important mineral is dimorphous, crystallising both in the cubic and rhombic systems, the latter variety being known by the special name of *Marcasite,* or *white iron pyrites.* Its composition is a bisulphide of iron, FeS^2, containing 46·7 per cent. of iron and 53·3 per cent. of sulphur; but on the large scale it almost invariably contains gold, from mere traces up to a workable quantity (several ounces per ton), and by intimate association with copper pyrites, copper; such varieties are known as *copper mundic,* to distinguish them from ordinary pyrites, or *sulphur mundic,* whose chief value is as a source of sulphuric acid.

Cubical pyrites occurs in variously-modified crystals, the usual forms being cubes or pentagonal dodecahedra, or combinations of both. The finest specimens are obtained in the iron mines of Elba and Traversella: the colour is of a brassy-yellow, with a nearly black streak, and the hardness (6 to 7) about that of soft steel; sp. gr. 4·9 to 5·1. When heated alone, a portion of the sulphur is volatilised, leaving a magnetic sulphide; but with the access of air the sulphur is burnt to sulphurous acid, and may be completely expelled, the iron passing into the state of peroxide, which, if sufficiently free from other substances may be utilised as an iron ore. This is a recent application, the material so obtained being known as *purple ore*, or *blue billy*. When exposed to moist air, pyrites becomes rapidly changed into sulphate of protoxide of iron, which, by a further absorption of oxygen, gives rise to numerous complicated minerals, containing peroxide of iron and sulphuric acid, known as basic persulphates. Marcasite is much more susceptible to such changes than the cubical form. When the oxidising action takes place very slowly, so that the sulphates may be removed as they are produced, pyrites may become completely changed into hydrated peroxide of iron without change of form. This is commonly observed in pseudomorphous crystals of pyrites, the resulting minerals containing about the same percentage of iron as the original: the change takes place without any great alteration of volume.

2. *Magnetic Iron Pyrites, Pyrrhotine.*—This mineral crystallises in the hexagonal system, and occurs chiefly in the crystalline rocks, in veins with various ores. Its colour is between bronze-yellow and copper-red, with a pinchbeck-brown tarnish; streak greyish-black; it is more or less magnetic. When heated in an open tube it yields sulphurous acid fumes, but no sublimate; before the blowpipe on charcoal in the reducing flame it fuses to a black strongly-magnetic globule; it is soluble in hydrochloric acid, evolving sulphuretted hydrogen and depositing sulphur. According to G. Rose, this mineral always contains a larger proportion of sulphur than corresponds with the simple sulphide FeS; and he adopts for it the formula $5FeS + Fe^2S^3$; corresponding with 60·44 iron and 39·56 sulphur, which agrees very closely with the analyses that have been made by Stromeyer, H. Rose, and others.

3. *Mispickel; Arsenical Iron; Arsenikkies.*—This mineral crystallises in the rhombic system, and is also found massive, granular, or columnar, and disseminated. It is brittle, with an uneven fracture; colour, silver-white, or almost steel-grey, with a greyish or yellowish tarnish; specific gravity 6 to 6·2. When heated in a closed tube it yields first a red, then a brown sublimate of sulphide of arsenic, and then metallic arsenic. Some varieties contain silver or gold, in others part of the iron is replaced by cobalt or nickel. Viewing it as a double sulphide and arsenide of iron, its formula would be $FeS^2 + FeAs$, which requires iron, 33·5; sulphur, 19·9; arsenic, 46·6. A specimen analysed by Plattner gave iron, 34·46; sulphur, 20·07; arsenic, 45·46. Mispickel is common in the mines of Freiberg in Saxony, and in the tin mines of Bohemia, Silesia, and in Cornwall. It is of no use as an ore of iron, but it is occasionally worked for the silver it contains, and as an ore of arsenic.

4. *Lölingite*, or *Leucopyrite; Glanzarsenikkies; Arseneisen, Mohsine;* contains iron, sulphur, and arsenic. It occurs at Reichenstein in Silesia, in serpentine, and is principally of interest from having been the first mineral from which gold was extracted by Plattner's process of acting on the burnt residues after the removal of arsenic with chlorine gas. (See CHLORINATION.) Dana gives the following analyses of Lölingite:—

	Arsenic	Sulphur	Iron	Nickel	Cobalt	
Reichenstein	65·99	1·94	28·06	...	...	*Hoffmann*
Fossinn	70·09	1·33	27·39	...	...	*Scheerer*
Schladming	60·41	5·20	13·49	13·37	5·10	*Hoffmann*

The name *leucopyrite* is derived from λευκός, *leukos*, white, and pyrites; it was given to the species by Shepard in 1835, antedating Haidinger's *Lölingite* and Chapman's *Mohsine*.

5. *Copper Pyrites, Chalcopyrite, Yellow Copper Ore.*—The common copper ore of Cornwall. It appears to be a double sulphide of copper and iron; its composition being, sulphur, 34·9; copper, 34·6; iron, 30·5. See COPPER.

6. *Tin Pyrites, Sulphide of Tin; Bell-metal Ore.*—This mineral is found in many of the Cornish mines. Its composition is—sulphur, 30·0; tin, 27·2; copper, 29·7; iron, 13·1.

The production of iron pyrites in the United Kingdom in 1872 and 1873 is shown at top of next page.

Imports of Pyrites of Iron, Copper, or Sulphur, in 1874.

500,831 tons; value 1,259,985*l.*

Iron pyrites, or mundic, is a mineral which is largely employed in the manufacture of copperas and of sulphuric acid. The pyrites ('brasses') of the Coal-measures are used in the preparation of copperas. Mr. Kirwan, in his 'Mineralogy,' gives us the following passage, which shows that the changes which take place in the sulphur ores (*Martial Pyrites*) had been well studied by him:—

'Vitriol is formed in these stones by exposing them a long time to the action of the air and moisture, or by torrefaction in open air, and subsequent exposure to its action, which operation in some cases must be often repeated, according to the proportion of

Production of Iron Pyrites in the United Kingdom in 1872 *and* 1873.

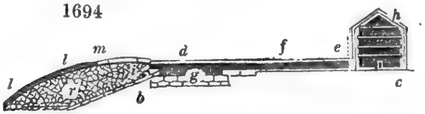
	1872						1873					
	Quantity			Value			Quantity			Value		
England:	tons	cwts.	qrs.	£	*s.*	*d.*	tons	cwts.	qrs.	£	*s.*	*d.*
Cornwall	2,176	18	0	1,435	3	1	1,806	2	0	1,367	3	2
Devonshire	2,758	5	2	2,516	11	2	2,732	8	0	2,881	14	11
Durham and Northumberland	3,250	0	0	2,437	0	0	2,450	0	0	2,000	0	0
Lancashire	3,000	0	0	2,250	0	0	2,275	0	0	1,500	0	0
Yorkshire	3,550	0	0	2,652	0	0	3,450	0	0	2,500	0	0
Staffordshire	4,000	0	0	3,000	0	0	3,750	0	0	2,000	0	0
Shropshire	19	6	0	9	18	0	64	0	0	32	0	0
Wales:												
Anglesea.	387	0	0	174	9	0	469	16	1	303	16	6
Carnarvonshire . . .	1,255	5	0	564	18	0	1,684	0	0	757	16	0
Carmarthenshire . . .	1,614	0	0	726	0	0	..			..		
Merionethshire . . .	954	0	6	430	0	0	179	0	0	109	0	0
Ireland	42,950	10	0	23,265	2	6	40,063	17	0	22,034	3	0
Total . . .	65,916	3	2	39,470	10	9	58,924	3	0	35,484	3	0

sulphur, and the nature of the earth; the calcareous pyrites are those in which it is most easily formed, and they effloresce the soonest. Good pyrites, properly treated, yield about two-thirds of their weight of vitriol.' See SULPHURIC ACID.

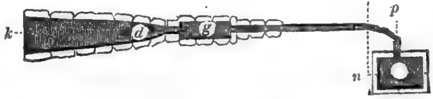
In the chemical works of Yorkshire the '*coal brasses*' are exposed in thin beds, which are often turned over to the action of the air. The sulphur is converted by the oxygen of the air into sulphuric acid, which combines with the iron, forming sulphate of protoxide of iron or *copperas,* which is dissolved out and crystallised. The same result may be obtained more quickly by roasting the sulphur ores.

Roasting of Pyrites.—Figs. 1694, 1695 represent a furnace which has been long employed at Fahlun in Sweden, and several other parts of that kingdom, for roasting iron pyrites in order to obtain sulphur. This apparatus was constructed by the celebrated Gahn. *Fig.* 1694 is a vertical section, in the line *k d n o* of *fig.* 1695, which is a plan of the furnace; the top being supposed to be taken off. In both figures the conduit may be imagined to be broken off at *e*; its entire length in a straight line is 43 feet beyond the dotted line *e n*, before the bend, which is an extension of this conduit. Upon the slope *a b* of a hillock *a b c*, lumps, *r*, of iron pyrites are piled upon the pieces of wood *i*, for roasting. A conduit, *d f e*, forms the continuation of the space denoted by *r*, which is covered by stone slabs so far as *f*, and from this point to the chamber, *h*, it is constructed in boards. At the beginning of this conduit there is a recipient, *g*. The chamber *h* is divided into five chambers by horizontal partitions, which permit the circulation of the vapours from one compartment to another. The ores *r*, being distributed upon the billets of wood *i i*, whenever these are fairly kindled, they are covered with small ore, and then with rammed earth, *l l*. Towards the point *m*, for the space of a foot square, the ores are covered with moveable stone slabs, by means of which the fire may be regulated, by the displacement of one or more, as may be deemed necessary. The liquid sulphur runs into the recipient *g*, whence it is laded out from time to time. The sublimed sulphur passes into the conduit *f e*, and the chamber *h*, from which it is taken out, and washed with water, to free it from sulphuric acid, with which it is somewhat impregnated; it is afterwards distilled in cast-iron retorts. The residuum of the pyrites is turned to account in Sweden for the preparation of a common red colour, much used as a pigment for wooden buildings.

1694



1695



Enormous quantities of iron pyrites exist in Spain, and are now being brought to this country. The sulphur ores contain a small quantity of copper, which increases their value.

In the year 1838 the King of Naples granted a monopoly of Sicilian sulphur to Messrs. Faix & Co. of Marseilles; this had the effect of greatly increasing the price of that substance, and the immediate result was the employment of iron pyrites as a source of sulphur in the manufacture of sulphuric acid. The consumption of this mineral materially increased from that date, and for many years the supply was principally derived from the mines of Cornwall and from those of Wicklow in Ireland.

About the year 1853 pyrites containing a small percentage of copper began to be imported from Spain and Portugal, and considerable quantities of ordinary pyrites are derived from Norway. The increased importance, however, of this branch of industry will be appreciated when it is stated that the annual importation into the United Kingdom of pyrites for the manufacture of sulphuric acid is about 450,000 tons, of which at least 321,500 tons contain a sufficient amount of copper to render its treatment, for that metal, commercially advantageous.

The principal mines from which the chemical trade is now supplied with cupreous pyrites are those of Mr. James Mason at San Domingos in Portugal, and those of the Tharsis Sulphur and Copper Company in the south of Spain. The ores from these localities do not differ very materially from each other; and the following analysis, made by Mr. Claudet, of a specimen from Mr. Mason's mines, may be taken as representing an average sample:—

Analysis of Mason's Pyrites.

Sulphur	48·90
Arsenic	·47
Iron	43·55
Copper	3·10
Zinc	·35
Lead	·93
Lime	·20
Insoluble rock	·73
Moisture	·70
Oxygen and loss	1·07
Total	100·00

In the manufacture of sulphuric acid this pyrites is burnt in kilns supplied with a limited amount of air; the products of combustion being thence conducted into leaden chambers, as in the case of vitriol manufactured from ordinary brimstone. The residue or 'burnt ore' was formerly, to a great extent, smelted for copper, and from the large amount of oxide of iron present acted as a valuable flux for more siliceous ores.

Burnt ore, resulting from the treatment of San Domingos pyrites, may be taken as having the following average composition:—

Analysis of Burnt Ore from the San Domingos Mines.

Sulphur	3·66
Arsenic	·25
Iron	58·25 = 83·00 Fe^2O^3
Copper	4·14
Zinc	·37
Cobalt	traces
Lead	1·24
Lime	·25
Insoluble matter	1·06
Moisture	3·85
Oxygen and loss	26·93
Total	100·00

Silver 18 dwts. per ton.

Soluble in water; sulphate of copper, 4·12 per cent. = 1·65 of copper.

The cinder, or burnt ore, which remains in the pyrites-kilns of the sulphuric-acid makers, although sometimes still smelted as a flux for other ores, is now generally treated by a process of wet extraction, conducted in the following way:—

The ore from which the principal portion of sulphur has been removed by burning, but which still retains from 3 to 5 per cent. of that body, and a nearly equal amount of copper, together with a little silver, is first mixed with 15 per cent. of rock-salt, and then reduced to a state of fine division, by being passed between powerful crushing rollers to which proper sieving apparatus is attached.

The ore thus ground, and ultimately mixed with salt, is next calcined in a reverberatory furnace at a low-red heat. By this calcination sulphur is oxidised, and the resulting sulphuric acid, combining with the sodium of the common salt, forms sodium sulphate; the copper, on the other hand, becomes converted into chloride by the action of liberated hydrochloric acid, and a highly soluble salt of that metal is the result.

This roasting with salt is sometimes conducted in revolving mechanical furnaces, somewhat similar to those employed for the calcination of tin ores in Cornwall; in other cases muffle-furnaces are employed, whilst in many establishments open reverberatory furnaces, heated by gas, are made use of; the flame being first taken beneath the tile-bottom forming the hearth, and afterwards through the body of the furnace. Whatever may be the form of furnace adopted, the flues in connection therewith are in communication with a condensing tower, packed with crenulated brickwork, through which a spray of water is constantly descending, which thus acquires a sufficient degree of acidity to render it of value during the succeeding operation of washing.

The acid waters from the condenser are also found to contain traces of copper, which is thus retained, and a certain amount of loss of that metal thereby prevented. When open furnaces are made use of, the amount of copper recovered is exceedingly small, and of little or no commercial value; it is however stated that when muffle-furnaces are employed, the quantity of that metal caught in the condensers is much more considerable. It must, however, be remembered that close furnaces consume a much larger amount of fuel than open ones, and that the time required for the operation is when they are employed much longer. It is therefore believed that any advantage to be derived from the recovery of a somewhat larger amount of volatilised copper is, in the case of the muffle-furnace, more than counterbalanced by the loss of time experienced and the increased expenditure of fuel.

In the close furnace the calcination of each charge of the mixture of ground burnt ore and common salt occupies twelve hours. In the open furnace heated by gas a charge of three tons is drawn every six hours. On being withdrawn from the furnace the calcined ore, whilst still warm, is taken in iron waggons to lixiviating vats.

These vary considerably in their dimensions, but a very convenient size is 11 feet square and 3 feet 6 inches deep. Each tank is provided with a false bottom of perforated tiles, supported on bricks placed on-edge, these are covered, to a depth of five inches, with sifted cinders, which form a filter, and on this is placed the ore to be lixiviated. The charge of a tank of the dimensions above given is about 15 tons. Each charge of the lixiviating vats generally receives some eight or ten successive washings, either with hot water, with weak copper-liquors, or with water acidulated by hydrochloric acid; the necessary amount of the latter is usually obtained from the condensing towers attached to the establishment, but in the case of very refractory ores this is not always found to be sufficient.

The washing-tanks require to be placed at a sufficient height above the floor to allow of the copper-liquors being tapped directly into wooden spouts, by which they are conveyed into a series of tanks of similar dimensions, where the copper is precipitated in the metallic state, by means of scrap-iron. This operation is facilitated by heating the solutions by a jet of steam conveyed into them through a leaden pipe.

In order to separate the cement-copper produced from the fragments of undissolved iron with which it is mixed, it is placed on a platform composed of plates of perforated cast iron, which forms the head of a box or tank filled with hot water to a depth of about four inches over the surface of the plates. It is here stirred briskly with an iron rake, by which the copper is made to pass through the holes in the 'grid,' whilst the fragments of iron, remaining on its surface, are raked off into shallow baskets, in which they are again taken to the precipitating vats.

The precipitated copper, which thus collects in the washing-box, is subsequently allowed to drain, and, after being dried in a properly-constructed stove, is either sold to the smelters, or is fused and refined in the establishment in which it is produced. The precipitate thus obtained from Spanish and Portuguese pyrites usually contains from 75 to 80 per cent. of copper, and a little over 20 oz. of silver per ton.

The spent ore, remaining in the lixiviating tanks, is washed until it retains only 0·20 per cent. of copper, when it is removed for the reception of a fresh charge of calcined ore. This substance, which is known as 'purple ore,' or 'blue billy,' meets with a ready sale to the various iron works, where it is chiefly employed for the fettling of puddling furnaces, although it is also extensively employed in the blast-furnace. It has the following average composition:—

Analysis of Purple Ore from Portuguese Pyrites.

Ferric oxide	96·00
Lead, as sulphate	0·75
Copper	0·20
Sulphur	0·36
Lime	0·40
Cobalt, Arsenic, and Chlorine	trace
Phosphorus	trace
Soda	0·10
Insoluble residue	2·11
Total	99·92

Although it has been long known to those engaged in copper-extraction that Spanish pyrites contains a notable quantity of silver, together with distinct traces of gold, no successful attempt to render it available had been made up to the year 1870, when Mr. F. Claudet patented a process for the separation of this metal from ordinary copper-liquors by the addition of a soluble iodide.

The amount of silver contained in burnt ore seldom exceeds 18 dwts. per ton, but as the whole of this is never obtained in solution, it follows, that in order to obtain satisfactory commercial results, the process adopted should be both economical and expeditious.

The tanks in which burnt ore, roasted with common salt, is lixiviated, usually receive from eight to ten successive washings, and the liquors from the first three of these contain nearly 95 per cent. of the total amount dissolved; the first three washings are therefore alone treated for the precious metals. For the purpose of removing the soluble salts from the roasted ore, hot water is first employed, and, as a large proportion of the sodium chloride used remains undecomposed, it acts as a solvent for the silver chloride produced during the operation of furnacing. The analysis of a first washing from a lixiviating tank gave Mr. Claudet the following results:—

Analysis of Strong Liquors.

Sp. Gr.=1·240	Contents per gallon
Sodium sulphate	10·092
„ chloride	4·474
Chlorine, combined with metals	4·630
Copper	3·700
Zinc	480
Lead	40
Iron	32
Calcium	52
Silver	3·06
Arsenic, antimony, bismuth, &c., not estimated	trace

Proportion of copper to silver, 10,000 : 8·2.

The several operations for the recovery of the silver are conducted in the following manner, and, as the first three washings contain nearly the whole of that metal, these are alone operated on:—

These liquors are first run into suitable wooden cisterns, each of a capacity of about 2,700 gallons, where they are allowed to settle.

The yield of silver per gallon of the solution is now ascertained by taking a measured quantity, to which are added hydrochloric acid, potassium iodide, and a solution of acetate of lead. The precipitate thus formed is thrown upon a filter, and, after being dried, is fused with a suitable flux. Argentiferous lead is thus obtained in the form of a button of convenient size, which is passed to the cupel, and from the weight of the resulting silver the amount of that metal, in a gallon of the copper-liquors, is readily calculated.

After thus determining the amount of silver contained in a gallon of the liquor to be operated on, it is drawn off into another vat, of slightly larger capacity than the settler, and, at the same time, the exact amount of some soluble iodide necessary to precipitate the silver present (a solution of kelp being employed by preference) is run into it from a graduated tank, together with a quantity of water equal to about one-tenth the volume of the copper-liquor. During the filling of the second tank its contents are constantly stirred, and, when filled, they are allowed to settle during 48 hours. The liquors are then run off, and the tank is again filled; the precipitate which is deposited in the bottom of these tanks is, about once a fortnight, washed into a vessel prepared for its reception.

This precipitate is chiefly composed of a mixture of lead sulphate, lead chloride, silver iodide, and subsalts of copper, from which the latter are removed by washing with water acidulated by hydrochloric acid. Thus freed from copper, the precipitate is decomposed by metallic zinc, which reduces the silver iodide completely, and also the lead chloride. The results of this decomposition are: 1st. A precipitate, rich in silver, containing a valuable amount of gold. 2nd. Zinc iodide, which, after being standardised, is employed in subsequent operations for the precipitation of silver.

The argentiferous precipitate finally obtained, after the decomposition of the iodides by metallic zinc, contains nearly 60 per cent. of lead, a trace of copper, and a little zinc; the amount of silver present varies from 1,500 to 2,000 oz. per ton; the yield of gold remains nearly constant at 20 oz. per ton. This process is employed at the Copper Extraction Works of Messrs. Muspratt Brothers and Bentley, Flint; at those of Messrs. Morris & Co., Stockwith-on-Trent; and at those of the Widnes Metal Co., Widnes. At the latter establishment the results of two years' regular working showed that 0·65 oz. of silver and 3 grs. of gold had been extracted from each ton of ore worked; leaving a profit of nearly 3*s.* per ton on the operation, after paying all expenses, including loss of iodide, &c.—J. A. P.

PYRITES, COBALT. See Cobalt.

PYRITES, COPPER. See Copper.

PYRITES, MAGNETIC. See Pyrites.

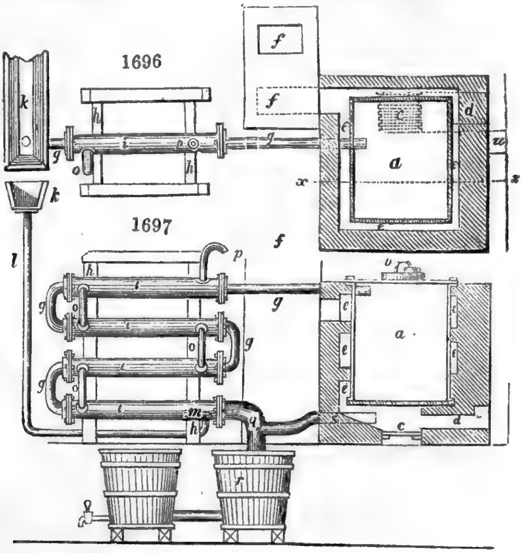
PYROACETIC SPIRIT. See Acetic Acid.

PYROGALLIC ACID. If gallic acid is carefully heated to about 400°, it is totally decomposed into carbonic acid and pyrogallic acid, which sublimes in brilliant white plates; it is easily soluble in ether, alcohol, and water; it reacts feebly acid, it fuses at 240°, and sublimes at 400°. If a solution containing peroxide of iron be added to a solution of pyrogallic acid, a black colour is struck, but the iron is rapidly reduced to a state of protoxide, and the liquor assumes a rich red tint.—*Kane.*

Dr. Stenhouse has fully investigated the formation of gallic and of pyrogallic acid; to his papers on this subject those interested are referred. Pyrogallic acid has of late years been largely employed in Photography, which see. It has also been used to dye the hair a light brown. See Gall Nuts.

PYROLIGNEOUS ACID. See Acetic Acid.

The apparatus represented in *figs.* 1696 and 1697 is a convenient modification of that exhibited under acetic acid, for producing pyroligneous acid. *Fig.* 1696 shows the furnace in a horizontal section drawn through the middle of the flue which leads to the chimney. *Fig.* 1697 is a vertical section taken in the dotted line *x*, *x*, of *fig.* 1696. The chest *a* is constructed with cast-iron plates bolted together, and has a capacity of 100 cubic feet. The wood is introduced into it through the opening *b*, in the cover, for which purpose it is cleft into billets of moderate length. The chest is heated from the subjacent grate *c*, upon which the fuel is laid, through the fire-door, *d*. The flame ascends spirally through the flues *e e*, round the chest, which terminate in the chimney, *f*. An iron pipe, *g*, conveys the vapours and gaseous products from the iron chest to the condenser. This consists of a series of pipes laid zigzag over each other, which rests upon a framework of wood. The condensing tubes are enclosed in larger pipes, *i i*; a stream of cold water being caused to circulate in the interstitial spaces between them. The water passes down from a trough *k*, through a conducting tube *l*, enters the lowest cylindrical case at *m*, flows thence along the series of jackets *i*, *i*, *i*, being transmitted from the one row to the next above it, by the junction-tubes *o*, *o*, *o*, till at *p* it runs off in a boiling-hot state. The vapours proceeding downwards in an opposite direction to the cooling stream of water, get condensed into the liquid state, and pass off at *q*, through a discharge-pipe, into the first close receiver *r*, while the combustible gases flow off through the tube *s*, which is provided with a stopcock to regulate the magnitude of their flame under the chest. As soon as the distillation



is fully set agoing, the stopcock upon the gas-pipe is opened; and after it is finished, it must be shut. The fire should be supplied with fuel at first, but after some time the gas generated keeps up the distilling heat. The charcoal is allowed to cool during 5 or 6 hours, and is then taken out through an aperture in the back of the chest, which corresponds to the opening *u*, *fig.* 1696, in the brickwork of the furnace. About 60 per cent. of charcoal may be obtained from 1,000 feet of fir-wood, with a consumption of as much brush-wood for fuel.

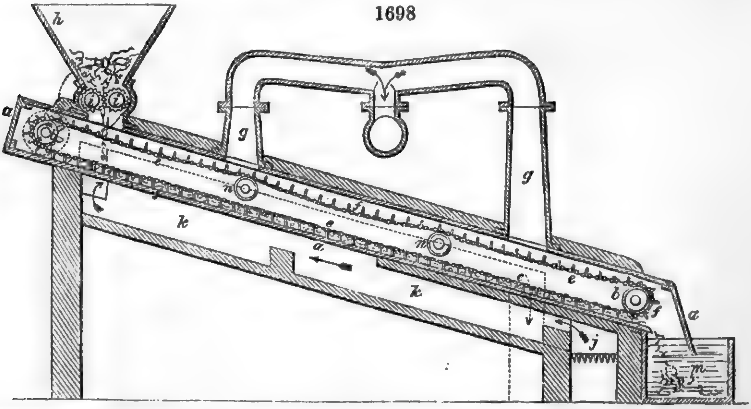
A new mode of distilling wood and producing this acid has been introduced by Mr. W. H. Bowers, of Manchester. In the rectangular retort which is used there are two revolving drums, one at each end. On these drums are endless chains; on these chains there is formed a flat surface by means of bars laid across. A hopper supplies this surface with the sawdust or other material to be heated. The surface is somewhat inclined. A very small engine is used to set the endless chain in motion. The sawdust is carried from the upper end of the retort to the lower, during which time it is exposed to heat and becomes distilled. At its lower end, as it is turning over the drum, it falls in a carbonised state into water. The vapours are carried away by pipes, as in the usual method, and the water-joint at the lower part of the retort prevents any escape in that direction, whilst the thickness of the mass of sawdust passing into the retort readily prevents any from passing out there. It is said that one retort can do the work of five of those made on Halliday's plan with the screw. Two of them produce with slow motion 2,500 gallons of acid in six days. The motion may be increased at will, and heat regulated accordingly. There are scrapers to prevent charcoal clogging the bars forming the inclined plane, and the apparatus does not require to be stopped for any purpose of cleansing. It feeds and discharges continuously, from month to month.

Sawdust, wood-turnings, small chips, spent dye-wood, and tanners' bark, peat, and such like ligneous and carbonaceous substances, are distilled, and the carbon discharged as shown.

It is believed also that the distillation is effected more rapidly, and the gases more directly removed by this method, than by any other.

Fig. 1698 is a longitudinal section taken through the middle of the retort or rectangular vessel *a*, *a*, *a*; *b*, *b* are the revolving drums on which the endless chain *e*, *e*, *e*, revolves; *f*, *f* are cross-bars or scrapers; *g*, *g*, are tubes to convey the gases, one from the lower and one from the higher point of the moving plane; *h* is a hopper filled with sawdust and other material to be distilled; the supply is regulated by two small cog-wheels *i*, *i*; *j*, the fire-place; *k*, *k*, the flues; *m* is a cistern showing the level of the water and the carbon falling into it, the lower part of the retort dipping into it. See ACETIC ACID; CREOSOTE.

1698



PYROLITHE. See EXPLOSIVE AGENTS.

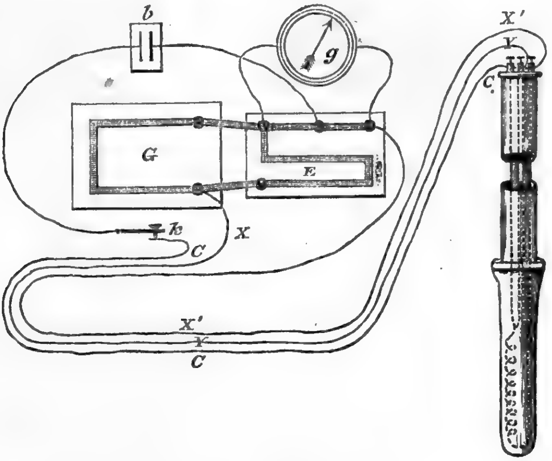
PYROLUSITE. Native peroxide of manganese. See MANGANESE.

PYROMETER. An instrument employed to measure temperatures which are too high to be determined by any thermometer. Some pyrometers have been constructed of bars of metal; the rates of expansion of which are known, and by which, therefore, any high degree of heat could be, with some precision, determined. The pyrometer of Wedgwood was formerly much employed; but it is a very defective instrument. It consists of two slightly convergent pieces of copper, between which a small cylinder of clay is set; the latter contracts by the heat, and the convergence is therefore increased. Its amount being measured, the heat to which the cylinder has been exposed can be calculated.

A good pyrometer is an instrument much wanted. Messrs. Siemens Brothers have devised a pyrometer which essentially consists of a length of fine platinum wire doubled back upon itself, and coiled upon a cylinder of refractory clay. The ends of the coil are fastened to stout platinum wires of such a length that their farther extremities never reach a very high temperature, and these in their turn are connected by copper wires with binding-screws on the outside case of the pyrometer. The copper wires are inclosed in a stout tube of wrought iron, about 3·5 centimeters in diameters and 120 centimeters long, which projects from the furnace or other space whose temperature is required, and forms a handle and support for the whole instrument. The part to be inserted in the furnace, namely, the coil of platinum wire, is protected by a case or sheath, which is fastened by screws to one end of the iron tube.

The indications depend on the changes which the electrical resistance of the platinum coil undergoes when its temperature is altered. *Fig.* 1699 will fully explain the whole arrangement. In order to avoid the errors which might otherwise arise from the heating of the leading wires connecting the pyrometer with the measuring apparatus, the undivided current of the testing battery is conveyed by a wire, which passes down the stem of the instrument, and is denoted by C in the figure, to the beginning of the pyrometer-coil, where it divides into two parts; one of which, after traversing the coil, is conveyed up the stem and back to the battery by the wire marked X, while the other part is conveyed by a precisely similar wire, X′, to the standard against which the coil is to be measured. Thus, in the comparison, the resistance-wire X acts as an addition to that of the pyrometer-coil, and that of the wire X′ as an equal addition to the resistance of the standard. In the figure, G represents the resistance coils; E the platinum-silver resistance coils; *b* the testing battery; *g* the galvanometer; and *k* the key.

1699



A committee of the British Association was appointed to report on the action of this electrical pyrometer. Some of their results will be found in the 'Reports of the British Association for 1872 and 1873.'

An Acoustical Pyrometer.—At the American National Academy of Science, at Cambridge, U.S.A., an interesting paper has been read by Dr. A. M. Mayer, of Hoboken, on an acoustical pyrometer. He commenced by giving a description of his method of measuring the surfaces of sound-waves. An open organ-pipe, provided with a König's nodal capsule, is connected with a small gas-jet placed in front of a revolving cubical mirror. Alongside of this jet is placed another of König's capsules, also furnished with a gas-jet, and attached to a heavy rubber tubing, some meters in length; to the other end of this tube one of Helmholtz's resonators is attached by means of its beak. The resonator and organ-pipe must both be of the same note. On sounding the organ-pipe the gas-jet attached to its capsule is alternately increased and diminished, and this flame, when viewed in the revolving mirror, appears to consist of a series of serrations; while, if viewed when the pipe is not sounding, it appears as a continuous band. If now the resonator be brought close to the mouth of the pipe, the flame attached to it is also agitated, and it is very easy to make the serrations of one flame correspond with those of the other by slight changes in the adjustment. If the resonator be removed gradually from before the mouth of the pipe, it will be seen that the serrations no longer coincide, but, at a certain point, the elevations of one flame coincide with the depressions of the other. On removing the resonator still farther, the crests again combine, and on removing it still farther they again separate. On measurement it is found that when the flames are in opposition, the distance of the resonator from its first position near the organ-pipe is just half a wave-length; and when they again coincide, the distance is a whole wave-length. This same object may be accomplished in another way, namely, by increasing the length of the tube connecting the resonator with its capsule. The resonators remaining stationary at the mouth of the pipe, the increased length of tube which it is necessary to add to make a trough correspond with a crest is equal to half a wave-length. He increases the length of the tube by means of two glass tubes, one of which slides air-tight into the other. If, instead of increasing the length of the tube, the air is rarefied by heating in the tube, the same object is accomplished—the same number of waves pass in a given time through the tube; but if the air is heated, each wave is increased in length, and consequently part of the waves are driven, as it were, out of the tube. Therefore, if the tube is made of iron, platinum, or other suitable material, and placed in a furnace, we shall see, as the tube is gradually heated, the crest of the flame corresponding to the resonator gradually passing away from the crest of the other flame, and finally corresponding with the second crest, and then with the third, and so on. By counting the number of waves thus driven out, and knowing the length of the tube, it is easy to calculate the length of the waves remaining in the tube, and from these lengths the increased temperature.

PYROPE, or *Bohemian Garnet.* From the mountains on the south side of Bohemia, imbedded in trap tufa. It occurs also at Zöblitz, in Saxony, in serpentine.

PYROPHORUS. The generic name of any chemical preparation which inflames spontaneously on exposure to the air. The sulphide of potassium is a good example of this when it is prepared with lamp-black, in the place of charcoal.

PYROTECHNY. (*Feux d'artifice*, Fr.; *Feuerwerke,* Ger.) The composition of luminous devices with explosive combustibles is a modern art resulting from the discovery of gunpowder. The finest inventions of this kind are due to the celebrated Ruggieri, father and son, who executed in Rome and Paris, and the principal capitals of Europe, the most beautiful and brilliant fire-works that were ever seen. The following description of some of their processes will probably prove interesting:—

The three prime materials of this art are, nitre, sulphur, and charcoal, with filings of iron, steel, copper, and zinc, and resin, camphor, lycopodium, &c. Gunpowder is used either in grain, half-crushed, or finely ground, for different purposes. The longer the iron-filings, the brighter red and white sparks they give; those being preferred which are made with a very coarse file, and quite free from rust. Steel-filings and cast-iron borings contain carbon, and afford a more brilliant fire, with wavy radiations. Copper-filings give a greenish tint to flame; those of zinc a fine blue colour; the sulphuret of antimony gives a less greenish blue than zinc, but with much smoke; amber affords a yellow fire, as well as colophony, and common salt; but the last must be very dry. Lamp-black produces a very red colour with gunpowder, and a pink with nitre in excess.

Golden showers are formed with lamp-black and nitre; yellow micaceous sand is also employed for the same purpose. All the copper salts tinge the flame green; those of strontia a red colour; and baryta and its salts also impart a peculiar green. Lycopodium burns with a rose colour and a magnificent flame; but it is principally employed in theatres to represent lightning, or to charge the torch of a Fury.

Fire-works are divided into three classes: 1, those to be set off upon the ground; 2, those which are shot up into the air; and 3, those which act upon or under water.

Composition for *jets of fire:* gunpowder, 16 parts; charcoal, 3 parts.

Brilliant revolving-wheel; for a tube less than ¾ of an inch: gunpowder, 16; steel-filings, 3. When more than ¾: gunpowder, 16; filings, 4.

Chinese or jasmine fire; when less than ¾ of an inch: gunpowder, 16; nitre, 8; charcoal (fine), 3; sulphur, 3; pounded cast-iron borings (small), 10. When wider than ¾: gunpowder, 16; nitre, 12; charcoal, 3; sulphur, 3; coarse borings, 12.

A fixed brilliant; less than ¾ in diameter: gunpowder, 16; steel-filings, 4; or gunpowder, 16, and finely-pounded borings, 6.

Fixed suns are composed of a certain number of jets of fire distributed circularly, like the spokes of a wheel. All the fusees take fire at once through channels charged with quick matches. *Glories* are large suns with several rows of fusees. *Fans* are portions of a sun, being sectors of a circle. *Patte d'oie* is a fan with only three jets.

The *Mosaic* represents a surface covered with diamond-shaped compartments, formed by two series of parallel lines crossing each other. This effect is produced by placing at each point of intersection, four jets of fire, which run into the adjoining ones. The intervals between the jets must be associated with the discharge of others, so as to keep up a succession of fire in the spaces.

Cascades imitate sheets or jets of water. The Chinese fire is best adapted to such decorations.

Fixed stars. The bottom of a rocket is to be stuffed with clay, the vacant space is to be filled with the following composition, and the mouth covered with pasteboard, which must be pierced into the preparation, with five holes, for the escape of the luminous rays, which represent a star:—

	Ordinary	Brighter	Coloured
Nitre	16	12	0
Sulphur	4	6	6
Gunpowder-meal . .	4	12	16
Antimony	2	1	2

Lances are long rockets of small diameter, made with cartridge-paper. Those which burn quickest should be the longest. They are composed as follows:—

White lances: nitre, 16; sulphur, 8; gunpowder, 4 parts.

Blueish-white lances: nitre, 16; sulphur, 8; antimony, 4 parts.

Blue lances: nitre, 16; antimony, 8 parts.

Yellow lances: nitre, 16; sulphur, 8; gunpowder, 16; amber, 8 parts.

Yellower lances: nitre, 16; sulphur, 4; gunpowder, 16; colophony, 3; amber, 4 parts.

Greenish lances: nitre, 16; sulphur, 6; antimony, 6; verdigris, 6 parts.

Pink lances: nitre, 16; gunpowder, 3; lamp-black, 1.

Cordage is represented by imbuing soft ropes with a mixture of nitre, 2; sulphur, 16; antimony, 1; resin of juniper, 1 part.

The Bengal flames consist of nitre, 7; sulphur, 2; antimony, 1. This mixture is pressed strongly into earthen porringers, with some bits of quick-match strewed over the surface.

Revolving suns are wheels upon whose circumference rockets of different styles are fixed, and which communicate by *conduits*, so that one is lighted up in succession after another. The composition of their common fire is, for sizes below $\frac{3}{4}$ of an inch: gunpowder-meal, 6; charcoal, not too fine, 3. For larges sizes: gunpowder, 20; charcoal, not too fine, 4. For *fiery radiations:* gunpowder, 16; yellow micaceous sand, 2 or 3. For *mixed radiations:* gunpowder, 16; pitcoal, 1; yellow sand, 1 or 2.

The *waving or double Catherine wheels*, are two suns turning upon the same axis in opposite directions. The fusees are fixed obliquely and not tangentially to their peripheries. The wheel-spokes are charged with a great number of fusees; two of the four wings revolve in one direction, and the other two in the opposite; but always in a vertical plane.

The *girandoles*, *caprices*, *spirals*, and some others have on the contrary a horizontal rotation. The fire-worker may diversify their effects greatly by the arrangement and colour of the jets of flame. Let us take for an example the *globe of light*. Imagine a large sphere turning freely upon its axis, along with a hollow hemisphere, which revolves also upon a vertical axis passing through its under pole. If the two pieces be covered with coloured lances or cordage, a fixed luminous globe will be formed, but if horizontal fusees be added upon the hemisphere, and vertical fusees upon the sphere, the first will have a relative horizontal movement, the second a vertical movement, which, being combined with the first, will cause it to describe a species of curve, whose effect will be an agreeable contrast with the regular movement of the hemisphere. Upon the surface of a revolving sun, smaller suns might be placed, to revolve like statellites round their primaries.

Ruggieri exhibited a luminous serpent pursuing with a rapid winding pace a butterfly which flew continually before it. This extraordinary effect was produced in the following way:—Upon the summits of an octagon he fixed eight equal wheels turning freely upon their axles, in the vertical plane of the octagon. An endless chain passed round their circumference, going from the interior to the exterior, covering the outside semi-circumference of the first, the inside of the second, and so in succession; whence arose the appearance of a great festooned circular line. The chain, like that of a watch, carried upon a portion of its length, a sort of scales pierced with holes for receiving coloured lances, in order to represent a fiery serpent. At a little distance there was a butterfly constructed with white lances. The piece was kindled commonly by other fire-works, which seemed to end in their play, by projecting the serpent from the bosom of the flames. The motion was communicated to the chain by one of the wheels, which received it like a clock from the action of a weight. This remarkably curious mechanism was called by the artists a *salamander*.

The rockets which rise into the air with a prodigious velocity are among the most common, but not least interesting, fire-works. When employed profusely they form those rich volleys of fire which are the crowning ornaments of a public fête. The cartridge is similar to that of other jets, except in regard to its length, and the necessity of pasting it strongly, and planing it well; but it is charged in a different manner. As the sky-rockets must fly off with rapidity, their composition should be such as to kindle instantly throughout their length, and extricate a vast volume of elastic fluids. To effect this purpose, a small cylindric space is left vacant round the axis; that is, the central line is tubular. The fire-workers call this space 'the soul of the rocket' (*l'âme de la fusée*). On account of its somewhat conical form, hollow rods, adjustable to different sizes of broaches or skewers, are required in packing the charge; which must be done while the cartridge is sustained by its outside mould, or copper cylinder. The composition of sky-rockets is as follows:—

When the bore is . . .	$\frac{3}{4}$ of an inch;	$\frac{3}{4}$ to 1;	$1\frac{3}{8}$.
Nitre	16	16	16
Charcoal . . .	7	8	2
Sulphur . . .	4	4	4
Brilliant Fire.			
Nitre	16	16	16
Charcoal . . .	6	7	8
Sulphur . . .	4	4	4
Fine steel-filings . .	3	4	5
Chinese Fire.			
Nitre	16	16	16
Charcoal . . .	4	5	6
Sulphur . . .	3	3	4
Fine borings of cast iron	3 coarser	4	5

The cartridge being charged as above described, the *pot* must be adjusted to it, with the *garniture;* that is, the serpents, the crackers, the stars, the showers of fire, &c. The pot is a tube of pasteboard wider than the body of the rocket, and about one-third of its length. After being strangled at the bottom like the mouth of a phial, it is attached to the end of the fusee by means of twine and paste. These are afterwards covered with paper. The garniture is introduced by the neck, and a paper plug is laid over it. The whole is enclosed within a tube of pasteboard terminating in a cone, which is firmly pasted to the pot. The quick-match is now finally inserted into the *soul* of the rocket. The rod attached to the end of the sky-rockets, to direct their flight, is made of willow or any other light wood. M. Ruggieri replaced the rod by conical wings, containing explosive materials, and thereby made them fly farther and straighter.

The *garnitures* of the sky-rocket pots are the following:—

Stars are small, round, or cubic solids, made with one of the following compositions, and soaked in spirits. *White stars:* nitre, 16; sulphur, 8; gunpowder, 3. Others more vivid consist of nitre, 16; sulphur, 7; gunpowder, 4.

Stars for golden showers: nitre, 16; sulphur, 10; charcoal, 4; gunpowder, 16; lamp-black, 2. Others yellower are made with nitre, 16; sulphur, 8; charcoal, 2; lamp-black, 2; gunpowder, 8.

The *serpents* are small fusees made with one or two cards; their bore being less than half an inch. The *lardons* are a little larger, and have three cards. The *retilles* are smaller. Their composition is, nitre, 16; charcoal, not too fine, 2; gunpowder, 4; sulphur, 4; fine steel-filings, 6.

The *petards* are cartridges filled with gunpowder and strangled.

The *saxons* are cartridges clayed at each end, charged with the brilliant burning fire, and perforated with one or two holes at the extremity of the same diameter.

The *cracker* is a round or square box of pasteboard, filled with granulated gunpowder, and hooped all round with twine.

Roman candles are fusees which throw out very bright stars in succession. With the composition (as under) imbued with spirits and gum-water, small cylindric masses are made, pierced with a hole in their centre. These bodies, when kindled and projected into the air, form the stars. There is first put into the cartridge a charge of fine gunpowder of the size of the star; above this charge a star is placed; then a charge of composition for the Roman candles.

The *stars*, when less than $\frac{3}{4}$ of an inch, consist of nitre, 16; sulphur, 7; gunpowder, 5. When larger, of nitre, 16; sulphur, 8; gunpowder, 8.

Roman candles, nitre, 16; charcoal, 6; sulphur, 3. When above $\frac{3}{4}$ of an inch, nitre, 16; charcoal, 8; sulphur, 6.

The *girandes*, or bouquets, are those beautiful pieces which usually conclude a firework exhibition; when a multitude of jets seem to enblazon the sky in every direction, and then fall in golden showers. This effect is produced by distributing a number of cases open at top, each containing 140 sky-rockets, communicating with one another by quick-match strings planted among them. The several cases communicate with each other by *conduits*, whereby they take fire simultaneously, and produce a volcanic display.

The *water fire-works* are prepared like the rest; but they must be floated either by wooden bowls, or by discs and hollow cartridges fitted to them.

Blue fire for lances may be made with nitre, 16; antimony, 8; very fine zinc-filings, 4. Chinese paste for the stars of Roman candles, bombs, &c.:—Sulphur, 16; nitre, 4; gunpowder-meal, 12; camphor, 1; linseed oil, 1; the mixture being moistened with spirits.

The *feu Grègeois* of Ruggieri, the son:—Nitre, 4; sulphur, 2; naphtha, 1

The *red-fire* composition is made by mixing 40 parts of nitrate of strontia, 13 of flowers of sulphur, 5 of chlorate of potash, and 4 of sulphuret of antimony.

Green fire may be made by using nitrate of baryta, instead of nitrate of strontia. Chloride of thallium also imparts a fine green colour to pyrotechnic mixtures.

White fire is produced by igniting a mixture of 48 parts of nitre, $13\frac{1}{4}$ sulphur, $7\frac{1}{4}$ sulphuret of antimony; or, 24 nitre, 7 sulphur, 2 realgar; or, 75 nitre, 24 sulphur, 1 charcoal; or, finally, 100 of gunpowder-meal, and 25 of cast-iron fine borings.

The *blue-fire* composition is, 4 parts of gunpowder-meal, 2 of nitre, sulphur and zinc, each 3 parts,

Picrate of ammonia is now used for the production of very brilliant coloured flames.

Prof. Church has published the following very interesting process for the production of coloured flames:—Bibulous paper is soaked for ten minutes in a mixture of 4 parts, by measure, of oil of vitriol with 5 parts of strong fuming nitric acid, and when washed out thoroughly with warm distilled water, is dried at a gentle heat. The gun-paper thus prepared is then saturated with chlorate of strontium, with chlorate of barium, or with nitrate of potassium, by immersion in a warm solution of these salts; a solution of chlorate of copper also may be used. If, after complete drying, a small pellet of any of these papers be made, lighted at one point at a flame, and then thrown into the air, a flash of intensely-coloured light is produced, while the combustion is so perfect that there is no perceptible ash. The barium salt gives a beautiful green light, the strontium salt a crimson, the potassium salt a violet, and the copper salt a fine blue. The chlorate may be prepared sufficiently pure for these experiments by mixing warm solutions of the chlorides of barium, strontium, or copper, with an equivalent quantity of a warm solution of chlorate of potassium. The clear liquid is to be poured off the precipitated chloride of potassium, and employed for the saturation of different portions of the gun-paper. The foregoing makes an admirable lecture-experiment, for illustrating the colours imparted to flame by barium, strontium, and other salts.

PYROXANTHINE. A substance detected in pyroxylic spirit by Mr. Scanlan. He thus describes this compound:—

If potash-water be added to raw wood-spirit (*pyroligneous*), as long as it throws down anything, a precipitate is produced, which is *pyroxanthine*, mixed with tarry matter. The precipitate is to be collected on a filter-cloth, and submitted to a strong pressure between folds of blotting-paper; it is next to be washed with cold alcohol, spec. grav. 0·840, in order to free it from any adhering tarry matter; when the pyroxyline is left nearly pure. If it be dissolved in boiling alcohol, or hot oil of turpentine, it crystallises regularly on cooling, in bright square prisms, of a fine yellow colour, that look opaque to the naked eye, but when examined under the microscope, have the transparency and colour of ferroprussiate of potash. Its turpentine-solution affords crystals of a splendid orange-red colour, having the appearance of minute plates, whose form is not discernible by the naked eye, but when examined by the microscope, they are seen to be thin right rectangular prisms. The orange-red colour is only the effect of aggregation; for when ground to powder, these crystals become yellow; and under the microscope, the difference in colour between the two is very slight. Its melting-point is 318° Fahr. It sublimes at 300° in free air; heated in a close tube in a bath of mercury, it emits vapour at 400°; it then begins to decompose, and is totally decomposed at 500°. Sulphuric acid decomposes it, producing a beautiful blue colour, which passes into crimson, as the acid attracts water from the atmosphere, and it totally disappears on plentiful dilution with water, leaving carbon of a dirty brown colour. Its alcoholic or turpentine-solution imparts a permanent yellow dye to vegetable- or animal- matter.

Pyroxanthine consists, according to the analysis of Drs. Apjohn and Gregory, of carbon, 75·275; hydrogen, 5·609; oxygen, 19·116, in 100 parts.

PYROXYLIC SPIRIT. Syns. *Pyroligneous spirit*, *Pyroligneous ether*, *Wood-spirit*, *Wood-naphtha*, *Methylic alcohol*, *Hydrate of methyle*, *Hydrated oxide of methyle*. $C^2H^4O^2 = C^2H^3O,HO$ (**CH^4O**). Density of strongest wood-spirit at 32°, 0·8179. Density at 68°, 0·798. Density of vapour, 1·12 = 4 volumes. Boiling-point, 150° Fahr.

Wood-spirit was first recognised as a distinct substance by Taylor, in 1812. Its true nature, however, was unknown until the appearance of the important research of MM. Dumas and Peligot, in 1835.

Pyroxylic spirit is obtained from the liquid products of the distillation of wood by taking advantage of its superior volatility. The crude wood-vinegar, if distilled *per se*, yields up to a certain point highly impure and weak spirit. It is, however, free from ammonia and alkaloïds. If, on the other hand, the vinegar is first neutralised by lime or soda previous to the distillation of the spirit, it is rendered more free from acetate of methyle and some other impurities, but it then contains alkaloïds and ammonia. At times the quantity of the latter substance present is so large that the spirit smokes strongly on the approach of a rod dipped in hydrochloric or acetic acid. In order to apply this test, it is obvious that the hydrochloric acid must be diluted until it does not fume by itself. By repeated rectifications over lime or chalk, rejecting the latter portions, the wood-spirit may be obtained colourless, and of a strength varying from 80 to 90 per cent. of pure spirit, the specific gravity being from 0·870 to 0·830.

Inasmuch as wood-spirit boils at a temperature far less than the point of ebullition of the impurities ordinarily found in it, it may always be greatly improved in solvent power, appearance, and odour, by mere rectification on the water-bath or in a rectifying-still. But, nevertheless, a certain quantity of the more volatile impurities always accompany the methylic alcohol, being carried over with its vapour. Among the foreign bodies may be mentioned the hydrocarbons of the benzole series. These may be entirely removed by mixing the crude spirit with three or four times its volume of water; the hydrocarbons are thus rendered insoluble and rise to the surface of the fluid. By means of a separator the lower layer may be removed, and after two or three rectifications, at as low a temperature as possible, the spirit may be procured quite clean.

To obtain wood-spirit quite pure it is generally recommended to mix it with chloride of calcium, and again rectify on a steam- or water-bath. By operating in this manner, the methylic alcohol combines with the chloride of calcium, forming a compound not decomposable at the temperature of the water-bath. The impurities present therefore distil away, leaving in the still a compound of pure methylic alcohol with chloride of calcium. But this latter compound possesses little stability, and may be decomposed by the mere addition of water, which liberates the spirit. It is then to be distilled away from the salt, and after one or two rectifications over quick-lime will be quite pure.

It is highly important that wood-spirit should be of considerable purity if required for the purpose of dissolving the gums. It is true, that so far as its use for dissolving shellac is concerned, there is no need for extreme purity, as shellac will dissolve in most specimens of wood-spirit. But it is not in this case the mere solvent power that is required; for if a solution of shellac in impure wood-spirit be employed by hatters, the vapour evolved is so irritating to the eyes that the workmen are unable to proceed. If the spirit has the property of fuming on the approach of a rod dipped in acetic or hydrochloric acids, it may be taken for granted that it will be incapable of dissolving gum-sandarach. This arises from the fact that such spirit has been distilled from an alkaline base, such as lime or soda, and contains alkaloïds, ammonia, and various other impurities which destroy its solvent power. The alkaline reaction may be destroyed and the spirit rendered fit for use by adding 2 or 3 per cent. of sulphuric acid and then distilling. The alkaloïds and many other impurities will then be retained, and the spirit may either be used at once or still further purified by dilution with water and subsequent rectification. It is possible to combine the two processes at one operation, by diluting the spirit with four times its bulk of water, and adding just enough oil of vitriol to the diluted liquid to give it a faint acid reaction to litmus-paper. It is absolutely essential to the success of this process that the mixture of spirit, water, and acid be perfectly well mixed.

A wood-spirit which refuses to dissolve sandarach may often be rendered a good solvent by adding from 5 to 7 per cent. of acetone. See ACETONE.

When wood-spirit is required in a state of extreme purity for the purpose of research, it may be obtained by distilling oxalate of methyle with water. Oxalate of methyle, or methyle oxalic ether may be prepared by distilling equal parts of sulphuric acid, oxalic acid, and wood-spirit. The distillate when evaporated very gently yields crystals of the compound in question. As it does not volatilise below 322° F., the retort containing the materials for its preparation requires to be pretty strongly heated to bring the ether over. It may be purified by sublimation from oxide of lead.

Pure methylic alcohol is a colourless transparent liquid, neutral, very inflammable, burning with a blue flame like common alcohol. It has a very nauseous flavour, and is fiery in the mouth. It dissolves in any proportion in water, alcohol, or ether, and is a good solvent for fatty bodies and certain resins. It is miscible with essential oils.

Wood-spirit may be detected even when greatly diluted with alcohol, by the brown colour which it assumes in presence of solid caustic potash. Even when alcohol contains only 2 per cent. of wood-spirit, it acquires a yellow tint in ten minutes on addition of powdered caustic potash. In half an hour the colour becomes brown.

According to Mr. Maurice Scanlan, wood-spirit may be distinguished from acetone (with which it appears to have sometimes been confounded in medicine), by the action of a saturated solution of chloride of calcium, which readily mixes with the former, but separates immediately from the latter.

Wood-spirit is but seldom employed now in the arts, as it is generally cheaper and more convenient to use the mixture of 90 parts of spirit of wine with 10 parts of purified wood-spirit, which is now permitted by Government to be employed free of duty under the title of 'methylated spirit.'

The following table contains the percentages of pure wood-spirit of the specific gravity 0·8136 in various mixtures; the temperature at which the experiments must be made to correspond with the above table being 60° F.—

Specific gravity	Real spirit per cent.	Over Excise proof	Specific gravity	Real spirit per cent.	Over or under proof
·8136	100·00		·9032	68·50	13·10
·8216	98·00	64·10	·9060	67·56	11·40
·8256	96·11	61·10	·9070	66·66	9·30
·8320	94·34	58·00	·9116	65·00	7·10
·8384	92·22	55·50	·9154	63·30	4·20
·8418	90·90	52·50	·9184	61·73	2·10
·8470	89·30	49·70			Under proof
·8514	87·72	47·40	·9218	60·24	0·60
·8564	86·20	44·60	·9242	58·82	2·50
·8596	84·75	42·20	·9266	57·73	4·00
·8642	83·33	39·90	·9296	56·18	7·00
·8674	82·00	37·10	·9344	53·70	11·00
·8712	80·64	35·00	·9386	51·54	15·30
·8742	79·36	32·70	·9414	50·00	17·80
·8784	78·13	30·00	·9448	47·62	20·80
·8820	77·00	27·90	·9484	46·00	25·10
·8842	75·76	26·00	·9518	43·48	28·80
·8876	74·63	24·30	·9540	41·66	31·90
·8918	73·53	22·20	·9564	40·00	34·20
·8930	72·46	20·60	·9584	38·46	35·60
·8950	71·43	18·30	·9600	37·11	38·10
·8984	70·42	16·30	·9620	35·71	40·60
·9908	69·44	15·30			

According to M. Deville, the above table is not absolutely correct, the spirit used by Dr. Ure not having been entirely free from water. M. Deville's numbers are as follow:

Specific gravity	Percentage of wood-spirit
0·8070	100
0·8371	90
0·8619	80
0·8873	70

Specific gravity	Percentage of wood-spirit
0·9072	60
0·9232	50
0·9429	40
0·9576	30
0·9709	20
0·9751	10
0·9857	5

Wood-spirit unites with chloride of calcium with such energy that the liquid enters into ebullition. The product of the union is sufficiently stable to endure a heat considerably above the boiling-point of water, without giving off the alcohol. Water, however, destroys the compound, and enables the spirit to be distilled away on the water-bath.

Methylic alcohol, treated with solution of bleaching powder, yields chloroform, but the resulting product is not so fine as that prepared from the vinic alcohol. In fact, methylic alcohol is seldom or never found in commerce of such purity as to enable good chloroform to be prepared by the action of chloride of lime. Moreover, it should be mentioned that so acrid and pungent are the products of the action of chlorine on the bodies accompanying crude wood-spirit, that great danger would be incurred in using a chloroform containing even minute traces of them. The following equation represents the action of the chlorine of the bleaching powder on wood-spirit:—

$$\underbrace{C^2H^4O^2}_{\text{Wood-spirit.}} + 4Cl = \underbrace{C^2HCl^3}_{\text{Chloroform.}} + 2HO + HCl. \quad (\mathbf{CH^4O + 4Cl = CHCl^3 + H^2O + HCl.})$$

C. G. W.

PYROXYLINE is one of the names given to gun-cotton. See GUN-COTTON.

PYRRHOTINE. Magnetic pyrites. See PYRITES.

PYRROL. C^8H^5N ($\mathbf{C^4H^5N}$). A volatile organic base, discovered in coal-naphtha by Rungé. It has been chiefly studied by Dr. Anderson. Its vapour possesses the singular property of dyeing fir-wood, moistened with hydrochloric acid, a deep red.

Q

QUANNET, THE. A kind of file. It is especially used for scraping zinc-plates for the process denominated anastatic printing.

QUARTATION is the alloying of one part of gold, that is to be refined, with three parts of silver, so that the gold shall constitute one *quarter* of the whole, and thereby have its particles so far separated as to be able to protect the other metals originally associated with it, such as silver, copper, lead, tin, palladium, &c., from the action of the nitric or sulphuric acid employed in the parting process. See REFINING.

QUARTZ. Silex; pure silica in the insoluble state. Quartz includes, as sub-species: *Rock-crystal*, *Rose-quartz*, *Amethyst*, *Prase* or *Chrysoprase*, and several varieties of chalcedony, as *Cat's-eye*, *Plasma*, *Chrysoprase*, *Onyx*, *Sardonyx*, *&c.* Lustre of quartz, vitreous, inclining sometimes to resinous; colours, very various; fracture conchoïdal; hardness, 7; specific gravity, 2·69. See SILICA.

QUASSIA is the wood of the root of the *Quassia excelsa*, a tree which grows in Surinam, the East Indies, &c. It affords to water an intensely bitter decoction, which is occasionally used in medicine, and was formerly substituted by some brewers for hops, but is now prohibited under severe penalties. It affords a safe and efficacious fly-water, or poison for flies.

QUEEN'S METAL. An alloy formed of 2 parts of tin and 1 part each of lead, antimony, and bismuth.

QUEEN'S WARE. See POTTERY.

QUEEN'S WOOD. See BRAZIL WOOD.

QUEEN'S YELLOW. Turbith's mineral; the yellow subsulpnate of mercury.

QUERCITRON is the bark of the *Quercus nigra*, or yellow oak, a tree which grows in North America. The colouring principle of this yellow dye-stuff has been called *Quercitron*, by its discoverer, Chevreul. If forms small pale yellow spangles, like those of *Aurum musivum*; has a faint acid reaction, is pretty soluble in alcohol, hardly in ether, and little in water. Solution of alum developes from it, by degrees, a beautiful yellow dye. See CALICO-PRINTING.

QUICKLIME. Caustic lime. See LIME.

QUICKSILVER. *Imported* in 1874, 2,988,447 lbs.; value £841,208. See MERCURY.

QUILL. See FEATHERS.

QUINIDINE is one of the alkaloïds obtained from the cinchona barks, and is found in most of them. The quantity, however, varies with the quality of the bark; *Cinchona Calisaya*, or *yellow bark*, which is the most prized, containing *quinine*, with but little, if any, *quinidine*, while some of the Loxa barks contain *quinidine*, and some *cinchonine*, and little or no *quinine*; such are the H.O. Crown barks.

Quinidine was discovered in 1833 by MM. Henry and Delandre. It has the same composition as quinine, $C^{40}H^{24}N^2O^4$ ($\mathbf{C^{20}H^{24}N^2O^2}$), but is nevertheless a distinct alkaloïd.

It is obtained from the barks containing it in the same manner as quinine from the quinine-yielding barks; and owing to the employment of the inferior barks in the manufacture of this latter alkaloïd or its sulphate, some quinidine is always present in it, but from the greater solubility of the salts of quinidine, they principally remain in the mother-liquors, from which the sulphate of quinine has crystallised.

QUININE. This alkaloïd is found, together with four other alkaloïds, in the cinchona barks, of which there are numerous varieties, some containing principally *quinine*, as the *Calisaya* or yellow bark, which is the most valuable of all the barks on that account; others containing principally *quinidine* and *cinchonine*, with but little *quinine*.

Quinine is the principal of these alkaloïds, and is now manufactured on a very large scale for medicinal purposes, it being a valuable tonic and febrifuge.

It was usually prepared from the *C. Calisaya*, but, owing to the scarcity and high price of this bark, several of the inferior barks have been employed in its manufacture, and on that account the quinine of commerce frequently contains some of the other alkaloïds. The sulphate is the only salt of quinine which is manufactured for commercial purposes, and is generally known, though improperly, as 'Disulphate of quinine.'

The following is the process most generally followed in the manufacture of this salt:—The coarsely-powdered bark is digested with hot dilute sulphuric or hydrochloric acid for one or two hours; the liquor is strained off, and the bark treated with a fresh portion of still more dilute acid for the same time. This process may be repeated a third time, but the liquor then obtained, containing so little quinine, is used for a fresh portion of bark. The liquors from the first and second digestions are strained and mixed, and are then mixed with lime, magnesia, or carbonate of soda, until the liquid acquires a slight alkaline reaction, which may be known by its turning red litmus-paper blue. Owing to the solubility of quinine, to a certain extent, in milk of lime and chloride of calcium, carbonate of soda is the best to be used for this purpose. A precipitate is formed, which is separated from the supernatant liquid by straining through a cloth. This dark-coloured mass, which contains the alkaloïds, colouring-matter, some lime, and some sulphate of lime,—these latter, of course, only when both lime and sulphuric acid have been used in the process,—is treated with boiling ordinary alcohol, which dissolves the alkaloïds and colouring-matter. This solution is filtered, and the greater part of the alcohol removed by distillation, when a brown viscid mass remains; this is treated with dilute sulphuric acid, till the solution remains slightly acid; this solution is then digested with animal-charcoal, filtered, evaporated, and allowed to cool, when the sulphate of quinine crystallises out, together with some sulphate of quinidine or cinchonine, according to the barks which have been employed; but, owing to the greater solubility of these latter salts than the sulphate of quinine, they principally remain in the mother-liquors. When *pure* animal-charcoal has not been used, the sulphate of quinine is likely to be contaminated with some sulphate of lime, formed by the action of the sulphuric acid on the lime in the animal-charcoal; and in this process also some quinine is likely to be precipitated by the lime and lost in the animal-charcoal.

In order to separate the sulphate of quinine thus obtained from the sulphates of quinidine and cinchonine, advantage is taken of the greater solubility of the two latter salts, as above mentioned, and by several crystallisations the sulphate of quinine may be obtained nearly free from these salts. The quantity of sulphate of quinine obtained from each pound of bark of course varies with the bark used. Some of the best *Calisaya* bark will yield half an ounce of the sulphate from every pound of bark, while many other barks which are used in the manufacture of sulphate of quinine do not yield a quarter of an ounce.

A process has been patented by Mr. Edward Herring for the manufacture of sulphate of quinine without the use of alcohol, and it yields the article known as 'hospital sulphate of quinine' at the first crystallisation and without the use of animal-charcoal. The following is the outline of the process:—

The powdered bark is boiled in solution of caustic alkali (soda preferred), which removes the useless extractive, gummy matters, and colouring-matter. After being well boiled, the bark is washed and pressed. This process of boiling with alkali, &c., may be repeated, if necessary, and the bark, after being well washed and pressed, having become decolourised, is boiled with dilute sulphuric acid, being kept constantly stirred whilst boiling. After the separation of the liquid, the bark is boiled with a second portion of dilute acid, and sometimes with a third; but the liquid from the last boiling is kept to be used for a fresh portion of bark. The first and second portions are mixed, strained, and treated with soda, which precipitates the alkaloïds; the precipitate is washed and pressed, and then digested with dilute sulphuric acid, which dissolves the alkaloïds; this solution is evaporated and allowed to cool, when the sulphate of quinine crystallises out, accompanied with some sulphates of quinidine and cinchonine, if the bark employed contained these latter alkaloïds in any quantity. The sulphate of quinine thus obtained is dried, and forms the unbleached or hospital quinine. When the sulphate of quinine is required quite pure, this is treated with *pure* animal-charcoal, and subjected to two or three further crystallisations.

It will be seen that the principal points in this process are the extraction of the colouring-matter by the caustic alkali and the use of *pure* animal-charcoal in producing the perfectly white sulphate, which prevents completely the admixture of sulphate of lime with the sulphate of quinine.

This process yields from 80 to 90 per cent. of the quinine contained in the bark employed; and to obtain the remaining 10 or 20 per cent. the blood-red solutions formed by boiling the bark with the caustic alkali are treated with dilute hydrochloric acid in excess, which retains in solution any alkaloïds that are present. This solution is strained and mixed with lime. The precipitate thus formed is collected, pressed, dried, and powdered.

It is then digested with *benzol*, or any solvent which is not a solvent of lime. These various tinctures or preparations are well agitated with dilute sulphuric acid, which extracts the quinine, &c.; when allowed to settle, the *benzol*, *oil of turpentine*, or *lard*, whichever has been used, rises to the surface. The acid liquid is then syphoned off and evaporated, and the sulphate of quinine obtained from it is purified by two or three crystallisations, when it yields a salt equal to that obtained by the first process, viz. the unbleached or hospital sulphate of quinine.

The sulphate of quinine of commerce is the neutral sulphate, and has the following composition:—$2C^{40}H^{24}N^2O^4,2HSO^4 + 14$ aq. ($\mathbf{2C^{20}H^{24}N^2O^2,H^2SO^4 + 7H^2O}$).

When pure it occurs as white spangles, or slender needles, which are slightly flexible, and possess a pearly lustre and an intensely bitter taste. It effloresces in the air, and loses about 12 atoms of water (*Baup*). It requires for solution, 740 parts of cold water and 30 parts of boiling water, 60 parts of alcohol at ordinary temperatures, and much less of boiling alcohol.

Its solution in acidulated water turns the plane of polarisation strongly to the left, and presents a blue tint, which is due to a peculiar refraction of the rays of light on the first surface of the solution, and is termed *fluorescence* by Professor Stokes, who, as well as Sir John Herschel, has examined the cause of it, the latter referring it to epipolic dispersion.

Heated to 212° F., sulphate of quinine becomes luminous, which is augmented by friction, and the rubbed body is found to be charged with a vitreous electricity, sensible to the electroscope. It fuses easily, and in that state resembles fused wax; at a higher temperature it assumes a red colour, and at length becomes charred. When a solution of quinine is treated with chlorine and ammonia, it yields a bright green solution, very characteristic of quinine.

Besides the neutral sulphate, there exists an acid sulphate, or *bisulphate*, of the following composition:—$C^{40}H^{24}N^2O^4,2HSO^4 + 16HO$. ($\mathbf{C^{20}H^{24}N^2O^2,H^2SO^4 + 8H^2O}$).

It is formed by dissolving the neutral sulphate in dilute sulphuric acid, evaporating and crystallising. It crystallises in rectangular prisms, or silky needles. It is much more soluble in water than the neutral sulphate, requiring only 11 parts of water at ordinary temperatures to dissolve it. The solution reddens blue litmus-paper.

It fuses in its water of crystallisation, and at 212° F. loses 24·6 per cent. of water (*Liebig* and *Baup*). With sulphate of sesquioxide of iron, it forms a double salt, which crystallises in octahedra resembling those of alum.

Adulteration of sulphate of quinine.—Owing to the high price of sulphate of quinine, it is often adulterated with various substances, as alkaline and earthy salts, boracic acid, sugar, starch, manite, margaric acid, salicine, sulphates of cinchonine and quinidine; the two latter substances will be found in most of the commercial sulphate of quinine, and are not looked upon as fraudulent mixtures when present only in small quantities, arising then from the imperfect purification of the sulphate of quinine. Sometimes, however, sulphate of cinchonine is present in large quantities, and this is effected by briskly stirring the solution from which the sulphate of quinine is crystallising, when, although under other circumstances the sulphate of cinchonine would remain in solution, it will by this agitation be deposited in a pulverulent form, together with the sulphate of quinine. No doubt this fraud had been practised to a considerable extent. See CINCHONA BARK.

R

RABBET. That part of the keel, and stern stern-post of a ship which is cut for the plank of the bottom to fit into.

RABBIT (*Lepus cuniculus*). This well-known little animal is not only employed largely as food, but it furnishes to manufactures useful articles in its skin. The quantity used in this country and on the Continent is enormous.

RABBLE. *A metallurgical tool.* The stirring-tool used in the process of puddling iron. See IRON.

RABBLING. The working of iron in a puddling-furnace with the rabble.

RACK. An inclined plane on which the ore and slime are washed and separated. *Racking* is the process of separating the heavy metallic ores from the earthy matter with which they are mixed.

RADICAL or **RADICLE, CHEMICAL.** In modern chemistry, a group of elements which is common to a series of allied compounds. See Watts's 'Dictionary of Chemistry.'

RADICALS, ALCOHOL. Hydrocarbons, such as methyl and ethyl, which may be supposed to exist in the alcohols. Thus ordinary ethyl-alcohol, $C^4H^6O^2$ ($\mathbf{C^2H^6O}$), may be regarded as a compound of the radical ethyl, C^4H^5 ($\mathbf{C^2H^5}$), with the group of elements HO^2 (hydroxyl $\mathbf{HO}$).

RAFFAELLE WARE. A name sometimes applied to Majolica ware. This pottery was made in the city of Urbino, and it has been said that the designs for many of the pieces were 'furnished by the scholars of Raffaelle from the original drawings of their great master,' and hence the name. See MAJOLICA.

RAG. Any hard coarse-grained rock, whether sedimentary or eruptive, is provincially called 'rag'; hence such stones as Kentish rag, Rowley rag, &c.

RAGS. The fragments and shreds of linen, cotton, or woollen fabrics. Linen and cotton rags are collected from all quarters for the purpose of making paper-pulp. The quantity imported annually is seldom less than 11,000 tons. Woollen rags of every kind are worked up into *mungo* and *shoddy*. (See these terms.) Coarse cloths and druggets are made of them; and the fine dust of woollen rags is used in preparing the beautiful flock-papers with which our rooms are decorated. They are also used largely for manure. The lands for cultivating the early broccoli which are brought to the London market from the western part of Cornwall are dressed with woollen rags in preference to any other manure. See PAPER.

The following abstract of information included in Reports respecting the Export Duty on Rags in foreign countries will be of interest in connection with our paper-manufactories:—

			Value
			£
Austria, rags and paper-pulp exported in 1872 in Zoll. centners of 110·25 lbs.		26,734	18,713
Denmark, in 1872	lbs.	2,046,580	
Italy, rags of vegetable substances	kilos.	12,537,000	
„ of other substances	„	1,183,000	
Portugal, rags for making paper, 1871	„	14,341	
woollen rags	„	7,802	Roubles
Russia,	pouds of 36 lbs.	658,018	658,018
Spain, 1873	kilos.	155,403	
Switzerland	cwts.	2,987	
Ottoman Empire	okes	2,652,992	

RAG-STONE. A variety of hone-slate used for sharpening steel instruments upon. The Norway rag-stone is well known.

RAG-WOOL. The wool obtained by tearing up in a machine constructed for the purpose. Woollen rags, called also SHODDY.

RAILS. The manufacture of iron and steel rails has, with the extension of our railway system, increased in a remarkable manner. This is, however, rather a subject for a treatise on mechanical engineering, than for a Dictionary of Manufactures.

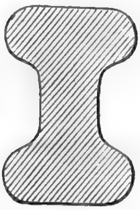
Rails are made by passing bars of iron, when red hot, through rollers with indentations or grooves in their peripheries, corresponding with the intended shape of the rails; the rails thus formed present the same surface to the bearing of the wheels, and their depths being regulated according to the distance from the point of bearing, they also present the strongest form of section with the least material.

Malleable iron rails were formerly always employed. An objection has been urged against these rails on the ground that the weight on the wheels rolling on them expanded their upper surface, and caused it to separate in thin laminæ. In many of our large stations rails may be frequently seen in this state; layer after layer breaking off, but this may be regarded rather as an example of defective manufacture than anything else. It is true, Professor Tyndall has referred to those laminating rails, as examples in proof of his hypothesis, that lamination is always due to, and is always produced by, mechanical pressure upon a body which has freedom to move laterally. Careful examination, however, shows that whenever lamination of the rail becomes evident, it can be traced to the imperfect welding together of the bars of which the rail is formed.

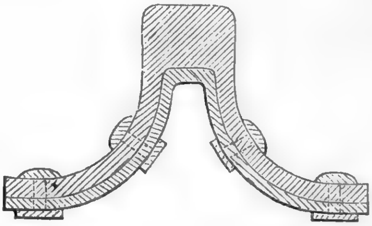
The weight of railway bars varies according to section and length. There are some of 40 pounds per yard, and some of 80 pounds, almost every railway company employing bars of different weight. Beside flat rails, which are occasionally still used, we have bridge rails employed, which have the form of a reversed U. These have sometimes parallel sides, or, as in dovetail rails, the sides are contracted. The ∩-rails are more easily manufactured than the I-rails, the difficulty of filing the flanges not being so great as in the latter rail.

Fig. 1700 represents the old rail, and *fig.* 1701 Mr. W. H. Barlow's patent rail, which is made to form its own continuous bearing. In section this rail somewhat resembles an inverted V, with its ends considerably turned outwards. This portion forms the surface by which the rail bears upon the ballasting, the apex of the Λ being formed with flanges in the ordinary form of rails: and the rail, therefore, beds throughout on the ballast. Rails of Vignole's section are now extensively employed. Steel rails, especially those made from Bessemer steel, are becoming very generally used. They are found to wear very much longer than the iron rail, and are specially useful at points, crossings, and stations where the wear is exceptionally heavy.

1700



1701



RAISINS are grapes allowed to ripen and dry upon the vine. The best come from the south of Europe, as from Roqueviare in Provence, Calabria, Spain, and Portugal. Fine raisins are also imported from Smyrna, Damascus, and Egypt. Sweet fleshy grapes are selected for maturing into raisins, and such as grow upon the sunny slopes of hills sheltered from the north winds. The bunches are pruned, and the vine is stripped of its leaves, when the fruit has become ripe; the sun then beaming full upon the grapes completes their saccharification, and expels the superfluous water. These are *muscatels* or *blooms*. The raisins called *lexias* are plucked, cleansed, and dipped for a few seconds in a boiling lye of wood-ashes and quicklime, at 12° or 13° of Beaumé. The wrinkled fruit is lastly drained, dried, and exposed in the sun upon hurdles of basket-work during 14 or 15 days.

The finest raisins are those of the sun, so called; being the plumpest bunches, which are left to ripen fully upon the vine, after their stalks have been half cut through.

Valentia raisins are prepared by steeping them in boiling water, to which a lye of vine stems has been added.

Corinthian raisins or *currants* are obtained from a remarkably small variety of grape called the *black Corinth*. They are now grown in Zante, Cephalonia, and Patras.

RAKE VEIN, *in mining.* A vein cutting indifferently through all the strata; under some circumstances they are known as *gash veins* and *slip veins.*

RAM, HYDRAULIC. Originally invented by Montgolfier, in France, and patented by him in 1797.

This machine, which is self-acting, is composed of an air-vessel and 3 valves, 2 for the water and 1 for keeping up the supply of air. Upon pressing down the valve in the conducting tube, which opens downwards, the water escapes from it, until this momentum is sufficient to overcome the weight, when the valve immediately rises and closes the aperture. The water, having then no other outlet than the inner valve, rushes through it by its general force, compressing the air in the air-vessel until equilibrium takes place, when the air reacts by its expansive force, closing the inner valve, which retains the water above it, and driving it up the ascending tube. By this reaction the water is forced back along the conducting-pipe, producing a partial vacuum beneath the outer valve, which immediately falls by its own weight. The water thus escapes until it has acquired sufficient force to close this, when the action proceeds as before. It is best adapted for raising moderate quantities of water, as for household or farming purposes.

RAMMERS. *In mining,* an instrument used for compressing the powder in the hole for blasting. *In engineering,* the tool used for ramming earth, clay, or loam, in making dams and the like.

RAPE-SEED. (*Brassica campestris oleifera.*) Summer Rape, Wild Navew, or Colza. This and the winter rape (*B. Napus*) are the only sorts cultivated to any extent in Britain for the manufacture of oil, and growers generally agree that the former of these is to be preferred from its yielding a greater quantity of seed, in the proportion of 955 to 700. (*Lawson.*) See Colza.

RAPE-SEED OIL. See Oils.

RASPS AND FILES. File-making is a manufacture which is still in a great measure confined to Sheffield. It is remarkable that hitherto no machine has been constructed capable of producing files which equal those cut by the human hand. Machine-made files have not the 'bite' which hand-cut files have: this is accounted for by the peculiar facilities of the human wrist to accommodate itself to the particular angle suitable to produce the proper 'cut.' Small files are made out of the best cast steel; those of a larger size from ordinary steel; flat files are forged on an ordinary study; other forms on bolsters, with the indentature corresponding to the shape required being thereon impressed: a chisel wider than the blank to be cut is used as the only instrument to form the teeth; it is moved by the hand with the greatest nicety. After cutting, and previous to hardening, the file is immersed in some adhesive substance, such as ale-grounds, in which salt has been dissolved; this protects the teeth from the direct action of the fire; it is then immersed perpendicularly in water; cleaned, and finished.

The manufacture of rasps and files does not belong to this work. Those interested in it will find an elaborate description of all the varieties of files, and of their manufacture, in 'Turning and Mechanical Manipulation,' by Holtzapffel; and in 'Manufactures in Metal,' vol. i., *Iron and Steel,* revised by Mr. Robert Hunt.

RASP, MECHANICAL, is the name given by the French to an important machine much used for mashing beet-roots. See Sugar.

RATAFIA is the generic name, in France, of *liqueurs* compounded with alcohol, sugar, and the odoriferous or flavouring principles of vegetables. Bruised cherries with their stones are infused in spirit of wine to make the ratafia of Grenoble *de Teyssère.* The liquor being boiled and filtered, is flavoured when cold with spirit of *noyeau,* made by distilling water off the bruised bitter kernels of apricots, and mixing it with alcohol. Syrup of bay laurel and galango are also added. See Liqueurs.

RATTANS. The stems of the *Calamus rotang,* of *C. rudentum,* and various species of palms. They are used for caning chairs, as a substitute for whalebone, for walking-sticks, and many other purposes.

RAZORS. The manufacture of razors differs from the manufacture of the finer varieties of cutting instruments, only in the degree of care which is required to produce a perfect instrument.

Two workmen are always engaged in razor-making. The rod of steel of which they are made is about half an inch in breadth, and of sufficient thickness to form the back. The stake upon which they are forged is rounded on both sides of the tops, which is instrumental in thinning the edge, and much facilitates the operation of grinding. The blades are then hardened and tempered in the ordinary way, with the exception that they are placed on their back on an iron plate, and the moment they assume a straw colour of a deep shade they are removed.

The grinding follows, on a stone revolving in water; then glazing on a wooden disc. The fine polish is given by a wooden wheel, having its circumference covered with buff leather, which is covered with crocus. The ornamentation of the blade by etching with acid and gilding, if such be required, is the last process. See 'Manufactures in Metal,' as revised by Mr. Robert Hunt; and 'Mechanical Manipulation,' by Holtzapffel.

RAZOR-HONE. In the manufacturing of the razor, for the first process of setting, the Charnley-Forest stone is used, but the principal part of the setting is accomplished almost invariably on the German hone. Various kinds of hones are, however, sold under this name, and they are of course of various qualities. See HONES.

RAZOR-STROP. 'Perhaps for the razor-strop a fine smooth surface of calf-skin, with the grained or hair side outwards, is best. It should be pasted or glued down flat on a slip of wood, and for the dressing almost any extremely fine powder may be used—such as impalpably fine emery, crocus, natural and artificial specular iron, black lead, or the charcoal of wheat-straw; . . . combinations of these and other fine powders, mixed with a little grease and wax, have been with more or less mystery applied to the razor-strop. The choice appears nearly immaterial, provided the powders are exceedingly fine, and they are but sparingly used.

'One side of the strop is generally charged with composition; on the other side the leather is left in the natural state, and the finishing stroke is in general given on the plain side' (*Holtzapffel*). The razor-strop requires to be kept very clean, and it should be very sparingly used.

REALGAR, *Red sulphide of arsenic.* (*Arsenic rouge sulfuré*, Fr.; *Rothes Schwefelarsenik*, Ger.) This ore occurs in crystalline rocks, under the form of veins, as also in volcanic districts; for example, at the Solfatara near Naples; or sublimed in the shape of stalactites, in the rents and craters of Etna, Vesuvius, and other volcanoes. Specific gravity varies from 3·3 to 3·6. It has a fine scarlet colour in mass, but orange-red in powder, whereby it is distinguishable from cinnabar. It is soft, sectile, readily scratched by the nail; its fracture is vitreous and conchoïdal. It volatilises easily before the blowpipe, emitting the garlic smell of arsenic, along with that of sulphurous acid. It consists of 70 parts of arsenic and 30 parts of sulphur.

Nearly all the commercial realgar is an artificial product, prepared by submitting arsenical pyrites to distillation, or by heating arsenious acid and sulphur in due proportions. It is an energetic poison, more so than the native realgar, from the fact of its containing free arsenious acid. The principal use of realgar is for fireworks. *White Indian fire*, often used as a signal-light, contains 7 parts sulphur, 2 parts realgar, and 24 parts nitre. See ARSENIC and PYROTECHNY.

REAL VALUE. See IMPORTS and EXPORTS.

RÉAUMUR'S PORCELAIN. Glass in the process of working will often acquire a peculiar opacity. This appears to depend on a physical change, since by a carefully-constructed process a kind of crystallisation may be set up, producing this porcellanous appearance. Réaumur endeavoured to introduce a material of this description in the place of pottery: hence the name.

RECTIFICATION is a second distillation of alcoholic liquors, to free them from whatever impurities may have passed over in the first. See ALCOHOL and DISTILLATION.

RED, ANILINE. See ANILINE RED and ROSANILINE.

RED CHALK. An earthy ore of iron, used as a drawing material.

REDDLE. One of the ores of iron, having an earthy texture. It is found more or less mixed with earthy matter, and is used for marking sheep in some of the western counties. A fine variety occurs not far from Rotheram in Yorkshire, and at Wastwater in Cumberland. See IRON.

RED EBONY. See GRENADA CROCUS.

RED HÆMATITE. Native anhydrous oxide of iron. See HÆMATITE; IRON.

RED LEAD. *Minium or saturnine red.* A pigment formed by exposing litharge to the action of the air at a temperature of about 560°, by which it absorbs oxygen. See LEAD.

RED LIQUOR, when prepared by the dyer or printer, is a liquid compound of acetate of alumina, having in it a little sulphate of alumina and potash; and is prepared by dissolving 8 pounds of alum in boiling water, and adding to this a solution of 6 pounds of acetate of lead, and stirring the whole well together. Sulphate of lead is formed and deposited as a heavy mass at the bottom of the liquid. The clear supernatant liquid is red liquor.

Red liquor of commerce is a crude acetate of alumina, prepared from pyroligneous acid. See CALICO-PRINTING.

RED MARL. A *geological term*, designating the upper members of the New Red Sandstone formation.

RED OCHRE. An earthy oxide of iron. See IRON.

RED ORPIMENT. A pigment of a deep scarlet colour, prepared by burning the yellow native orpiment, a trisulphide of arsenic. See ARSENIC.

REDRUTHITE. A name given by Brooke and Miller to the *vitreous copper* of Phillips, from the circumstance that some fine varieties have been found in the mines near Redruth, although much finer are produced by the St. Just mines. It is the *chalcosine* of Greg and Lettsom, *cuivre sulfuré* of Haüy, and the *Kupferglanz* of Haidinger and Naumann. Redruthite is a disulphide of copper. See COPPER.

RED SANDERS WOOD. A hard and heavy wood, which is imported from Calcutta in logs. It is much used as a dye-wood, and occasionally for turning.

RED-SHORT. When iron is brittle at a red heat, it is said to be *red-short.*

REDUCING AGENTS. The agents used to separate the metal in the smelting processes. See METALLURGY.

REDUCTION. When the metal is separated from the substances—sulphur, oxygen, arsenic, &c.—with which it is combined, it is said to be reduced; reduction is the process employed.

RED WOOD. A wood used by dyers, which is obtained from the Siberian buckthorn, *Rhamnus erythroxylon.*

REED is the well-known implement of the weaver, made of parallel slips of metal or reeds, called dents. A thorough knowledge of the adaptation of yarn of a proper degree of fineness to any given measure of reed, constitutes one of the principal objects of the manufacturer of cloth; as upon this depends entirely the appearance, and in a great degree the durability, of the cloth when finished. The art of performing this properly is known by the names of *examining*, *setting*, or *sleying*, which are used indiscriminately, and mean exactly the same thing. The reed consists of two parallel pieces of wood, set a few inches apart, and they are of any given length, as a yard, a yard and a quarter, &c. The division of the yard being into halves, quarters, eighths, and sixteenths: the breadth of a web is generally expressed by a vulgar fraction, as $\frac{1}{4}$, $\frac{4}{4}$, $\frac{5}{5}$, $\frac{6}{5}$; and the subdivision by the eighths or sixteenths, or *nails*, as they are usually called, as $\frac{7}{8}$, $\frac{9}{8}$, $\frac{11}{8}$, &c., or $\frac{13}{16}$, $\frac{15}{16}$, $\frac{19}{16}$, &c. In Scotland, the splits of cane which pass between the longitudinal pieces or ribs of the reed are expressed by hundreds, porters, and splits, the porter is 20 splits, or $\frac{1}{5}$th of a hundred.

In Lancashire and Cheshire a different mode is adopted, both as to the measure and divisions of the reed. The Manchester and Bolton reeds are counted by the number of splits, or, as they are there called, dents, contained in 24$\frac{1}{4}$ inches of the reed. These dents, instead of being arranged in hundreds, porters, and splits, as in Scotland, are calculated by what is there termed *hares* or *bears*, each containing 20 dents, or the same number as the porter in the Scotch reeds. The Cheshire or Stockport reeds, again, receive their designation from the number of ends or threads contained in one inch, two ends being allowed for every *dent*, that being the almost universal number in every species and description of plain cloth, according to the modern practice of weaving, and also for a great proportion of fanciful articles.

Comparative Table of 37-inch reeds, being the standard used throughout Europe, for inens, with the Lancashire and Cheshire reeds, and the foreign reeds used for holland and cambric.

Scotch	Lancashire	Cheshire	Dutch holland	French cambric
600	20	34	550	653
700	24	38	650	761
800	26	44	740	870
900	30	50	832	979
1000	34	54	925	1089
1100	36	60	1014	1197
1200	40	64	1100	1300
1300	42	70	1222	1414
1400	46	76	1295	1464
1500	50	80	1387	1602
1600	52	86	1480	1752
1700	56	92	1571	1820
1800	58	96	1665	1958
1900	62	104	1757	2067
2000	66	110	1850	2176

In the above table, the 37-inch is placed first. It is called Scotch, not because it either originated or is exclusively used in that country; it is the general linen reed of all Europe; but in Scotland it has been adopted as the regulator of her cotton-manufactures.

The number of threads in the warp of a web is generally ascertained with considerable precision by means of a small magnifying glass, fitted into a socket of brass, under which is drilled a small round hole in the bottom plate of the standard. The number of threads visible in this perforation ascertains the number of threads in the standard measure of the reed. Those used in Scotland have sometimes four perforations, over any one of which the glass may be shifted. The first perforation is $\frac{1}{4}$ of an inch in diameter, and is therefore well adapted to the Stockport mode of counting; that is to say, for ascertaining the number of ends or threads per inch, the second is adapted for the Holland reed, being $\frac{1}{200}$th part of 40 inches; the third is $\frac{1}{700}$th of 37 inches, and is adapted for the now almost universal construction of Scotch reeds; and the fourth, being $\frac{1}{200}$th of 34 inches, is intended for the French cambrics. Every thread appearing in these respective measures, of course, represents 200 threads or 100 splits, in the standard breadth; and thus the quality of the fabric may be ascertained with considerable precision, even after the cloth has undergone repeated wettings, either at the bleaching-ground or dye-work. By counting the other way, the proportion which the woof bears to the warp is also known, and this forms the chief use of the glass to the manufacturer and operative weaver, both of whom are previously acquainted with the exact measure of the reed.

REFINERY SLAG. The cinders produced in the process of refining iron. See Iron.

REFINING. *In metallurgy*, the process of partially decarbonising pig-iron. The processes employed to obtain pure metals from regulus, or impure mixtures.

REFINING GOLD AND SILVER. See Gold.

REFRACTORY MINERALS. Such minerals as graphite or plumbago, mica, steatite, fire-clays, and the like, which endure without fusion a very high temperature. See Fire-Clay.

REFRIGERATION OF WORTS, &c. It is of great importance to effect the cooling of worts as rapidly as possible. The simplest mode of refrigeration is by exposing the hot liquor or wort in shallow vessels, called coolers, to the action of the atmosphere or a current of air, sometimes accelerated by fans rotating horizontally just above the surface of the liquor; but sometimes utensils called refrigerators are employed, and so constructed that a quantity of cold water should be brought into contact with the heated fluid.

A simple form of refrigerator is that of the worm used by distillers; and the reverse process is commonly used by brewers, viz. a stream of cold water passing through pipes in a zigzag form, laid horizontally in the shallow cooler. But in every construction of refrigerator heretofore used, the quantity of cold water necessarily employed in the operation, greatly exceeded the quantity of the fluid cooled, which, in some situations, where water cannot be readily obtained, was a serious impediment and objection to the use of such apparatus.

In August 1826, Mr. Yandall obtained a patent for an apparatus designed for cooling worts and other hot fluids, without exposing them to evaporation; and contrived a mode of constructing a refrigerator so that any quantity of wort or other hot fluid may be cooled by an equal quantity of cool water; the process being performed with great expedition, simply by passing the two fluids through very narrow passages, in opposite directions, so that a thin stratum of hot wort is brought into contact over a large surface with an equally thin stratum of cold water, in such manner that the heated water, when about to be discharged, still absorbs heat from the hottest portion of the wort, which as it flows through the apparatus is continually parting with its heat to water of a lower temperature flowing in the contrary direction; and however varied may be the form, the same principle should be observed.

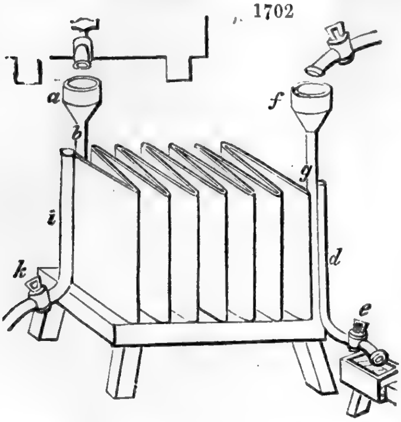
Figs. 1702, 1704, 1705, represent different forms in which the apparatus might be made; the two first having zigzag passages; the third, channels running in convolute curves. These channels or passages are of very small capacity in thickness, but of great length, and of any breadth that may be required, according to the quantity of fluid intended to be cooled or heated.

Fig. 1703 is the section of a portion of the apparatus shown at *figs.* 1702 and 1705 upon an enlarged scale; it is made by connecting three sheets of copper or any other thin metallic plates together, leaving parallel spaces between each plate for the passage of the fluids, represented by the black lines.

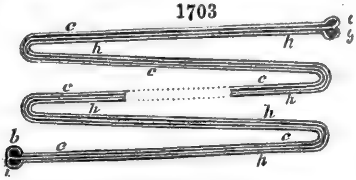
These spaces are formed by introducing between the plates thin straps, ribs, or portions of metal, to keep them asunder, by which means very thin channels are produced, and through these channels the fluids are intended to be passed, the cold liquor running in one direction, and the hot in the reverse direction.

Supposing that the passages for the fluids are each one-eighth of an inch thick,

1702



1703



then the entire length for the run of the fluid should be about 80 feet, the breadth of the apparatus being made according to the quantity of fluid intended to be passed through it in a given time. If the channels are made a quarter of an inch thick, then their length should be extended to 160 feet; and any other dimensions in similar proportions; but a larger channel than a quarter of an inch the patentee considered would be objectionable. It is, however, to be observed, that the length here recommended is under the consideration that the fluids are driven through the apparatus by some degree of hydrostatic pressure from a head in the delivery-vats above; but if the fluids flow without pressure, then the lengths of the passage need not be quite so great.

In the apparatus constructed as shown in perspective in *fig.* 1702, and further developed by the section, *fig.* 1703, cold water is to be introduced at the funnel *a*, whence it passes down the pipe *b*, and through a long slit or opening in the side of the pipe, into the passage *c*, *c* (*fig.* 1703), between the plates, where it flows in a horizontal direction through the channel towards the discharge-pipe *d*. When such a quantity of cold water has passed through the funnel *a*, as shall have filled the channel *c*, *c*, up to the level of the top of the apparatus, the cock *e*, being shut, then the hot wort or liquor intended to be cooled, may be introduced at the funnel *f*, and which descending in the pipe *g*, passes in a similar manner to the former, through a long slit or opening in the side of the pipe *g*, into the extended passage *h*, *h*, and from thence proceeds horizontally into the discharge-pipe *i*.

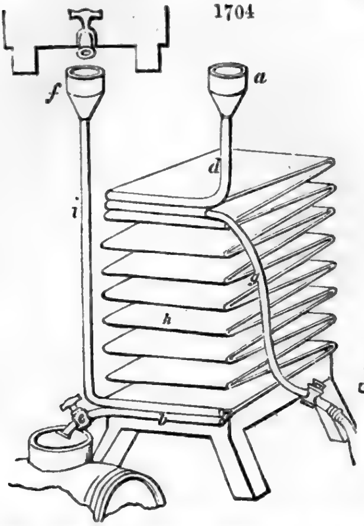
The two cocks *e* and *k*, being now opened, the wort or other liquor is drawn off, or otherwise conducted away through the cock *k*, and the water through *e*. If the apertures of the two cocks, *e* and *k*, are equal, and the channels equal also, it follows that the same quantity of wort, &c., will flow through the channel *h*, *h*, *h*, in a given time, as of water through the channel *c*, *c*; and by the hot fluid passing through the apertures in contact with the side of the channel which contains the cold fluid, the heat becomes abstracted from the former, and communicated to the latter; and as the hot fluid enters the apparatus at that part which is in immediate contact with the part where the cooling fluid is discharged, and the cold fluid enters the apparatus at that where the wort is discharged, the consequence is, that the wort or other hot liquor becomes cooled down towards its exit-pipe nearly to the temperature of cold water; and the temperature of the water, at the reverse end of the apparatus, becomes raised nearly to that of the boiling wort.

It only remains to observe, that by partially closing either of the exit-cocks, the quantity of heat abstracted from one fluid, and communicated to the other, may be regulated; for instance, if the cock *e* of the water-passage be partially closed, so as to diminish the quantity of cold water passed through the apparatus, the wort or other hot fluid conducted through the other passages will be discharged at a higher temperature, which in some cases will be desirable, when the refrigerated liquor is to be fermented.

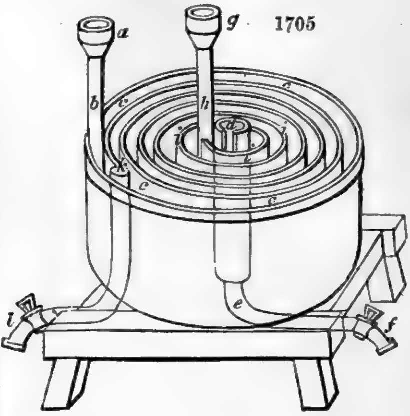
Fig. 1704 exhibits an apparatus precisely similar to the foregoing, but different in its position; for instance, the zigzag channels are made in obliquely descending planes. *a* is the funnel for the hot liquor, whence it descends through the pipe *d* into the channel *c*, *c*, *fig.* 1703, and ultimately is discharged through the pipe *b*, at the cock *e*. The cold water being introduced into the funnel *f*, and passing down the pipe *i*, enters the zigzag channel *h*, *h*, and, rising through the apparatus, runs off by the pipe *g*, and is discharged at the cock below.

The passages of this apparatus for heating and cooling fluids, may be bent into various contorted figures; and one of the most convenient forms, being very compact and easily cleaned, is that represented in *fig.* 1705, which consists of only two sheets of

1704



1705



thin copper, soldered together at their edges, forming a continuous spiral chamber for the passage of a thin stratum of water, and contained in a cylindrical case. The passages here run in convolute curves, the one winding in a spiral to the centre, the other receding from the centre.

The wort or other hot liquor intended to be cooled, is to be introduced at the funnel *a*, and passing down the pipe *b*, is delivered into the open passage *c*, which winds round to the central chamber *d*, and is thence discharged through the pipe *e*, at the cock *f*. The cold water enters the apparatus at the funnel *g*, and proceeding down the pipe *h*, enters the closed channel *i*, and after traversing round through the apparatus, is in like manner discharged through the pipe *k*, at the cock *l*. Or the hot liquor may be passed through the closed channel, and the cold through the open one; or these chambers may be both of them open at top, and the apparatus covered by a lid when at work, the principal design of which is to afford the convenience of cleaning them more readily than could be done if they were closed; or they may be both closed.

A similar ingenious apparatus for cooling brewers' worts, or wash for distillers, and also for condensing spirits in place of the ordinary worm-tub, is called by the inventor Mr. Wheeler, an Archimedes condenser, or refrigerator, the peculiar feature of which consists in forming the chambers for the passage of the fluids in spiral channels, winding round a central tube, through which spiral channels the hot and cold fluids are to be passed in opposite directions.

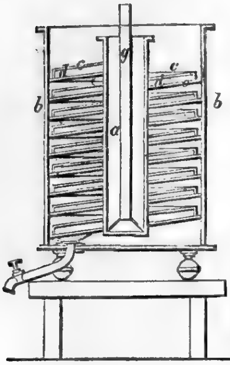
Fig. 1706 represents the external appearance of the refrigerator, enclosed in a cylindrical case; *fig.* 1707, the same, one-half of the case being removed to show the form of the apparatus within; and *fig.* 1708, a section cut through the middle of the apparatus perpendicularly, for the purpose of displaying the internal figure of the spiral channels.

In *figs.* 1707, 1708, *a, a*, is the central tube or standard (of any diameter that may be found convenient), round which the spiral chambers are to be formed; *b, b*, are the sides of the outer case, to which the edges of the spiral fit closely, but need not be attached; *c, c*, are two of the circular plates of copper, connected together by rivets at the edges, in the manner shown, or by any other suitable means; *d*, is the chamber, formed by the two sheets of copper, and which is carried round from top to bottom in a spiral or circular inclined plane, by a succession of circular plates connected to each other.

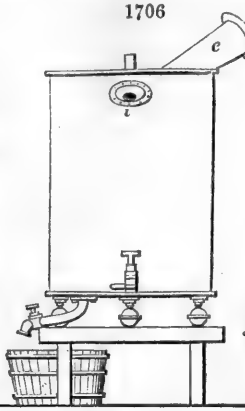
The hot fluid is admitted into the spiral chamber *d*, through a trumpet or wide-mouthed tube *e*, at top, and is discharged at bottom by an aperture and cock *f*. The cold water which is to be employed as the cooling material is to be introduced through the pipe *g*, in the centre, from whence, discharging itself by a hole at bottom, the cold water occupies the interior of the cylindrical case *b*, and rises in the spiral passage *n*, between the coils of the chamber, until it ascends to the top of the vessel, and then it flows away by a spout *i*, seen in *fig.* 1706.

It will be perceived that the hot fluid enters the apparatus at top, and the cold fluid at bottom, passing each other, by means of which an interchange of temperature takes place through the plates of copper, the cooling fluid passing off at top in a heated state, by means of the caloric which it has abstracted from the hot fluid; and the hot fluid passing off through the pipe and cock at bottom, in a very reduced state of temperature, by reason of the caloric which it held having been given out to the cooling fluid.

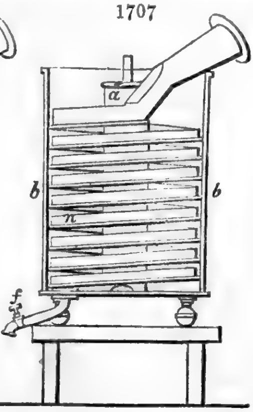
1708



1706

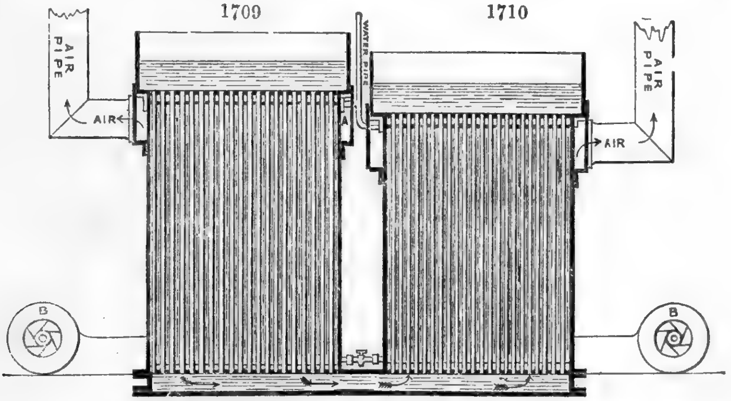


1707



Hodge's Patent Refrigerator for reducing the temperature of liquids.—This refrigerator is stated to be more effectual than anything yet offered to the public for cooling brewers' worts. The worts are passed down through the tubes in *fig.* 1709, and ascend through the tubes in *fig.* 1710. These tubes are of copper, and are encased in a chamber; water is let on under a head through the pipes A, sprinkling the outer surface of the tube with a jet, keeping them moist; at the same time a blast of cold air is blown into the chambers by the fans B B impinging on the surface, carrying away the caloric as fast as it is transmitted. Worts can be brought down from 212° to the desired temperature by this process cheaper and quicker than any other refrigerator; in fact, worts may be brought down to freezing temperature.

1709 1710



REFRIGERATOR. See Refrigeration of Worts.

REGENERATING FURNACE. See Iron and Steel.

REGENERATORS. A name given to arrangements for absorbing the heat, as it passes from the furnace, or place of combustion, and for parting with that heat to fresh air admitted to supply the furnace. By alternating the direction of circulation a saving of heat is effected. Dr. Percy suggests that *accumulators* would be a better term.

REGULUS. A name introduced by the alchemists, and applied by them in the first instance to antimony; it signifies *the little king;* and from the facility with which antimony alloyed with gold, these empirical philosophers had great hopes that this metal *antimony* would lead them to the discovery of the philosopher's stone.

'In the smelting of certain sulphuretted ores the product obtained in the first instance is a *sulphide* of the metal; and this product has received different names in different metallurgical works. In English copper works the word *metal* is commonly used to denote compounds of this kind, that of *regulus* being applied in a specific sense to certain kinds of *metal*. I shall, however, adopt the word *regulus* in the present work as a generic appellation for all similar products. The Germans designate regulus by the synonymous terms *Stein* and *Lech*, and the French by the term *matte*. It is frequently the case that in one smelting operation, *slag*, *regulus*, and *metal* are obtained, which are superposed in the order mentioned, which is that of their respective specific gravities.' (Percy, *Metallurgy*.)

In our metal-imports 'ore' and 'regulus' are commonly named. The regulus must be regarded as an impure metal.

REHEATING, *in metallurgy*. In iron manufacture, puddled bars are brought to a welding heat in furnaces, called *Reheating* or *Welding* furnaces, they are then passed through rolls to bring them into the condition of merchant iron.

REISNER. A process of inlaying wood, like Parquetry.

RELBUN. The South-American name for the roots of the *Calceolaria arachnoidea*, used for dyeing crimson by the natives.

RENNET. The gastric juice of the stomach of the sucking calf, which, being extracted by infusion immediately after the death of the animal, serves to curdle milk. As the juice passes rapidly into putrefaction, the stomach must be salted after the outer skin has been scraped off, and all the fat and useless membranes carefully removed. It is only the inner coat which is to be preserved after it is freed from any curd or other extraneous matter in the stomach. The serum left in it should be pressed out with a cloth, and is then to be replaced in the stomach with a large quantity of the best salt. The skins, or vells, as they are called, are next put into a pan and covered with a saturated solution of salt, and soaked for some hours; but there should be no more brine than covers the vells. They are afterwards hung up to dry, a piece of wood being put crosswise into each to stretch them out. They should be perfectly dried, and look like parchment. In this state they may be kept in a dry place for any length of time, and are always ready for use.

Pieces of vell are cut off and soaked for some hours in whey or water, and the whole is added to the warm milk for curdling it, its strength having been first tested on a small quantity. By the rapidity with which it curdles, and the form of the flakes, a judgment is formed of its strength, and the quantity required for the whole milk.

REPOUSSÉ. Metal-work in relief. The metal plate is placed upon a wax block, and by means of a punch and hammer, the ornamental design is hammered up.

RESIN, KAURI or **COWDEE,** is a peculiar resinous substance, imported from New Zealand. It oozes from the trunk of a noble tree called *Dammara Australis*. See DAMMAR.

RESINS (*Résines*, Fr.; *Harze*, Ger.) are principles found in most vegetables, and in almost every part of them; but the only resins which merit a particular description are those which occur naturally in such quantities as to be easily collected or extracted. They are obtained chiefly in two ways, either by spontaneous exudation from the plants, or by extraction by heat and alcohol. In the first case, the discharge of resin in the liquid state is sometimes promoted by artificial incisions made through the bark into the wood of the tree.

Resins possess the following general properties:—They are soluble in alcohol, in ether and the volatile oils, and with the aid of heat, combine with the unctuous oils. They may be combined by fusion with sulphur, and with a little phosphorus. They are insoluble in water, and melt by the application of heat, but do not volatilise without partial decomposition. They are almost all translucid, not often colourless, but generally brown, occasionally red or green. Any remarkable taste or smell, which they sometimes possess, may be ascribed to some foreign matter, commonly an essential oil. Their specific gravity varies from 0·92 to 1·2. Their consistence is also very variable. The greater part are hard, with a vitreous fracture, and so brittle as to be readily pulverised in the cold. Some of them are soft, a circumstance probably dependent upon the presence of a heterogeneous substance. The hard resins do not conduct electricity, and they become negatively electrical by friction. When heated they melt more or less easily into a thick viscid liquid, and concrete, on cooling, into a smooth shining mass, of a vitreous fracture, which occasionally flies off into pieces, like Prince Rupert's drops, especially after being quickly cooled, and scratched with a sharp point. They take fire by contact of an ignited body, and burn with a bright flame, and the diffusion of much sooty smoke. When distilled by themselves in close vessels, they afford carbonic acid and carburetted gases, empyreumatic oil of a less disagreeable smell than that emitted by other such oils, a little acidulous water, and a very little shining charcoal. See GAS, COAL.

Resins are little acted upon by acids, except by the nitric, which converts them into artificial tan. They combine readily with the alkalis and alkaline earths, and form what were formerly reckoned soaps; but the resins are not truly saponified; they rather represent the acid constituents themselves, and, as such, saturate the salifiable bases.

Every resin is a natural mixture of several other resins, as is the case also with oils; one principle being soluble in cold alcohol, another in hot, a third in ether, a fourth in oil of turpentine, a fifth in naphtha, &c. The soft resins, which retain a certain portion of volatile oil, constitute what are called balsams. Certain other balsams contain benzoic acid. The solid resins are, *amber, animé, benzoin, colophony* (common rosin), *copal, dammar, dragon's blood, elemi, guaiac, lac,* resin of *jalap, labdanum, mastic, sandarach, storax, takamahac.*

1. *The hard copal* of India and Africa, especially Madagascar, is the product of the *Hymenæa verrucosa.* It is transparent and vitreous within, whatever may be its appearance outside; nearly colourless, or of a tawny yellow; without taste or smell in the cold, and almost as hard as amber, which it much resembles, but from which it may be distinguished, 1st, by its melting and kindling at a candle-flame, and running down in drops, while amber burns and swells up without flowing; 2ndly, this hard copal when blown out and still hot, exhales a smell like balsam copaiva or capivi; while amber exhales an unpleasant bituminous odour; 3rdly, when moistened by alcohol of 85 per cent., copal becomes sticky, and shows, after drying, a glazed opaque surface, while amber is not affected by alcohol; 4thly, the copal affords no succinic acid, as amber does, on distillation.

Ether, boiling hot, dissolves 39·17 per cent. of copal.

Essence (spirits) of turpentine does not dissolve any of the copal, but it penetrates and combines with it at a heat of 212° Fahr.

2. *Resin of courbaril* of Rio Janeiro, the English gum-animé, and the semi-hard copal of the French. It is characterised by forming, in alcohol, a bulky, tenacious, elastic mass. It occurs in rounded tears, has a very pale glassy aspect, transparent within, covered with a thin white powder, which becomes glutinous with alcohol. Another variety is soft, and dissolves, for the most part, in alcohol; and a third resembles the oriental copal so much as to indicate that they may both be produced from the same tree. 100 parts of the oriental and the occidental animé yield respectively the following residua:—

	With alcohol	With ether	With essence
Oriental . . .	65·71	60·83	71
Occidental . . .	43·53	27·50	75·76

The hard and soft copals possess the remarkable property in common of becoming soluble in alcohol, after being oxygenated in the air.

3. *Dammar puti, or Dammar batu.*—This resin, soft at first, becomes eventually like amber, and as hard. It is little soluble in alcohol and ether, but more so in essence of turpentine.

4. *Aromatic dammar.*—This resin occurs in large orbicular masses. It is pretty soluble in alcohol. Only small samples have hitherto been obtained. Of 100 parts, 3 are insoluble in alcohol, none in ether, and 93 in essence of turpentine. M. Guibourt thinks that this resin comes from the Molucca isles. Its ready solubility in alcohol and great hardness render it valuable for varnish-making.

5. *Slightly aromatic dammar* leaves, after alcohol, 37 per cent.; and after ether 17 per cent.; and after essence, 87 per cent.

6. *Tender and friable dammar selan.*—This resin occurs in considerable quantity in commerce (at Paris). It is in round or oblong tears, vitreous, nearly colourless, and transparent within, dull whitish on the surfaces. It exhales an agreeable odour of olibanum, or mastic, when it is heated. It crackles with the heat of the hand, like roll-sulphur. It becomes fluid in boiling water, but brittle when cooled again. It sparkles and burns at the flame of a candle; but this being the effect of a volatile oil, the combustion soon ceases.—*Guibourt.*

RESINS, MINERAL. Petroleum, bitumen, asphalt, amber, and other mineral hydrocarbons are so called. See descriptions under the respective names.

RESIST. A paste used in calico-printing to keep portions white when the cloth is dipped into the dye. See CALICO-PRINTING.

RETENE. A hydrocarbon, similar to benzine, obtained from the resinous matter found on pine-stems in peat-bogs. It has also been obtained by the dry distillation of resinous pine-wood.

RETINITE. A mineral resin found in rounded or irregular lumps. It is soluble in alcohol, leaving an unctuous residue. It is found in the lignite beds of Bovey Tracey, in similar deposits in Hanover, and in the coal-mines of Moravia.

RETINOLE. A hydrocarbon, obtained from the turpentine-resins.

RETORT. Retorts may be of various shapes, and made of very different materials, according to the requirements. Some are of glass; others of clay. They may be made of any of the metals. Retorts are employed to effect the decomposition of compound bodies by the action of heat; sometimes alone, and sometimes aided by the action of other furnaces. They vary in shape; but generally may be regarded as consisting of a bulb and a beak. For producing coal-gas there are many modifications, varying in dimensions and shape with the caprice of the constructor.

RETURN AIR. In *coal-mining*, the air which ascends after having passed through the workings of a colliery.

RETURNS. A light-coloured and mild kind of tobacco.

REVALENTA ARABICA. The commercial name for the flour obtained from the lentil, *Ervum lens.* It was first called *Ervalenta,* then by transposing the letters of the first portion of the name, *revalenta* was obtained.

REVERBERATORY FURNACE. A furnace in which the flame passes over a bridge, and plays down—or reverberates against the hearth on which the materials are placed. See METALLURGY, COPPER, IRON, SODA, &c.

RHATANY ROOT. *Krameria triandra,* a native of Peru. The root is horizontal, very long and branched. It is used as an astringent, and in powder as a dentifrice.

RHODIUM. A metal discovered by Dr. Wollaston in 1803, in the ore of platinum. It is contained to the amount of 3 per cent. in the platinum-ore of Antioquia in Columbia, near Barbacoas; it occurs in the Ural ore, and alloyed with gold in Mexico. The palladium having been precipitated from the muriatic solution of the platinum-ore previously saturated with soda by the cyanide of mercury, muriatic acid is to be poured into the residuary liquid, and the mixture is to be evaporated to dryness, to expel the hydrocyanic acid, and convert the metallic salts into chlorides. The dry mass is to be reduced to a very fine powder, and washed with alcohol of specific gravity 0·837. This solvent takes possession of the double chlorides which the sodium forms with the platinum, iridium, copper, and mercury, and does not dissolve the double chloride of rhodium and sodium, but leaves it in the form of a powder of a fine dark-red colour. This salt being washed with alcohol, and then exposed to a very strong heat, affords the rhodium. But a better mode of reducing the metal upon the small scale consists in heating the double chloride gently in a glass tube, while a stream of hydrogen passes over it, and then to wash away the chloride of sodium with water.

Rhodium resembles platinum in appearance. According to Wollaston, the specific gravity of rhodium is 11. It is insoluble by itself in any acid; but when an alloy of it with certain metals, as platinum, copper, bismuth, or lead, is treated with aqua regia, the rhodium dissolves with the other metals; but when alloyed with gold or silver, it will not dissolve along with them. It may, however, be rendered very soluble by mixing it in the state of a fine powder with chloride of potassium or sodium, and heating the mixture to a dull red-heat, in a stream of chlorine gas. It thus forms a triple salt, very soluble in water. The solutions of rhodium are of a beautiful rose colour, whence its name. Its chief use at present is for making the unalterable nibs of the so-named rhodium pens.

The following remarks from a recent paper by Deville and Debray, '*On some properties of the so-called Platinum Metals,*' are full of interest. These chemists prepare rhodium by fusing platinum-residues with an equal weight of lead and twice its weight of litharge. When the crucible has attained a bright red heat, and the litharge is thoroughly liquid, the crucible is shaken once or twice, and is then allowed to cool slowly. The button of lead, which contains all the metals in the residue less oxidisable than lead, is treated with nitric acid, diluted with an equal volume of water, which removes, besides the lead, the copper and the palladium. The insoluble powder which remains is mixed with five times its weight of binoxide of barium, weighed exactly, and is heated to redness in a clay crucible for one or two hours. After this it is first treated with water, and then with aqua regia to remove the osmic acid. When the liquor has lost all smell, sufficient sulphuric acid is added to exactly precipitate the baryta. It is then boiled, filtered, and evaporated, first adding to it a little nitric acid and then a great excess of sal-ammoniac. The evaporation is carried to dryness at 212°, and the residuum is washed with a concentrated solution of sal-ammoniac, which removes all the rhodium. When the washings are no longer coloured, the liquor is evaporated with a great excess of nitric acid, which destroys the sal-ammoniac, and when only the salt of rhodium is left, the evaporation is finished in a porcelain crucible. The rhodium salt is now moistened with hydrosulphide of ammonia, mixed with three or four times its weight of sulphur, and the crucible is heated to bright redness, after which metallic rhodium is left in the crucible. So obtained rhodium may be considered almost pure, after it has been boiled for some time, first in aqua regia, and then in concentrated sulphuric acid. To obtain it perfectly pure it must be melted with four times its weight of zinc. The alloy is treated with concentrated hydrochloric acid, which dissolves most of the zinc, but leaves a crystalline matter which is really an alloy of rhodium and zinc in definite proportions. This is dissolved in aqua regia, and the solution is treated with ammonia until the precipitate first formed is redissolved. The solution is boiled and evaporated, by which is obtained the yellow salt, or chloride of rhodium. This is purified by repeated crystallisation, and then calcined with a little sulphur, by which means rhodium is procured absolutely pure.

Rhodium melts less easily than platinum, so much so that the same fire which will liquefy 300 grammes of platinum only will melt 40 or 50 grammes of rhodium. It is not volatilised, but it oxidises on the surface like palladium. Less white and lustrous than silver, it has about the same appearance as aluminium. When perfectly pure it is ductile and malleable, at least after fusion. Its density is 12·1.

The alloys of rhodium, those at least which have been examined, are true chemical combinations, as is shown by the high temperature developed at the moment of their formation. The alloy with zinc already described resists the action of muriatic acid, but in contact with air and the acid there is soon a well-marked rose-coloration which reveals an oxidation of the two metals under the double influence of the air and acid. The alloy with tin is crystallised, black, brilliant and fusible at a very high temperature.

RHODONITE. A silicate of manganese, sometimes containing iron, magnesium and calcium, found chiefly in Sweden.

RHOMB SPAR. Native carbonate of magnesia.

RHUBARB (*Rheum*). Thirteen species of plants have been named as yielding the medicinal rhubarb; it has, however, been recently determined that the *Rheum officinale* is the true rhubarb plant. The best rhubarb is called Turkey rhubarb, and only procured by the Russians, at Kiachta, from the Chinese. Several species of rhubarb are cultivated in this country, for the agreeable acidity of their stems.—See *Elements of Materia Medica*, by Bentley and Redwood.

RHUS. The Sumach, which see.

RHUSMA. *Rhusma turcorum.* Used as a depilatory.

RIABOCCA WOOD, or *Kiabocca wood*, an ornamental wood obtained from the East Indies. It is not known what tree produces it. It is much used for making ornamental boxes, desks, and the like.

RIBBON MANUFACTURE. This differs in no particular respect from the manufacture of woven fabrics in similar materials. See Silk, and Weaving.

RICE. (*Oryza sativa*, Linn.) This plant, originally a native of Asia, is now extensively cultivated in India, China, the islands of the Eastern Archipelago, in the West Indies, Central America, and the southern of the United States. Roxburgh informs us that there are above forty different varieties. Carolina and Patna rice are the kinds most esteemed in this country. Braconnot (*Ann. Chim. Phys.*) has given the following analyses of two varieties of rice:—

	Carolina rice	Piedmont rice
Starch	85·07	83·80
Woody fibre	4·80	4·80
Gluten	3·60	3·60
Tallowy oil	0·13	0·25
Sugar (uncrystallisable)	0·29	0·25
Gum	0·71	0·10

The inorganic constituents being, as estimated from the ash of the grain, as follows:—Potash, 18·48; soda, 10·67; lime, 1·27; magnesia, 11·69; oxide of iron, 0·45; phosphoric acid, 53·36; chlorine, 0·37; silica, 3·35.

Rice is used as food by a hundred millions of the inhabitants of the earth, and it is employed as an agreeable and nutritive diet in various forms by ourselves.

Rice imported in 1873.

	Quarters	Value
Rough and in the husk:		£
From Mauritius	2,248	3,380
„ British India :		
„ Madras.	4,605	10,644
„ Bengal and Burmah . . .	11,061	18,387
„ Other countries	858	1,129
Total	18,772	33,540
Ditto, not rough or in the husk:	Cwts.	£
From Holland	36,934	46,754
„ Japan	119,301	71,621
„ British India:		
„ Madras.	261,121	135,261
„ Bengal and Burmah . . .	6,008,225	2,920,204
„ Other countries	114,737	68,594
Total	6,540,318	3,254,434

	cwts.	£
Rice not in the husk imported in 1874 .	7,002,798	3,621,910

RICE CLEANING. Various machines have been contrived for effecting this purpose, of which that invented by Mr. Melvil Wilson may be regarded as a good example. It consists of an oblong hollow cylinder, laid in an inclined position, having a great many teeth stuck in its internal surface, and a central shaft also furnished with teeth. By the rapid revolution of the shaft, its teeth are carried across the intervals of those of the cylinder with the effect of parting the grains of rice, and detaching whatever husks or impurities may adhere to them. A hopper is set above to receive the rice, and conduct it down into the cleansing cylinder.

About 80 teeth are supposed to be set in the cylinder, projecting so as to reach very nearly the central shaft, in which there is a corresponding number of teeth, that pass freely between the former.

RICE-PAPER. A name given to the material on which the Hindoos and Chinese paint flowers, &c. It is the pith of the *Aralia papyrifera.* See PAPER.

RICE-STARCH. See STARCH.

RIDDING. *In mining*, a term used in the Newcastle coal-field for the operation of separating the iron ore from the coal-shale.

RIDER. *In mining*, a projecting piece of rock crossing a fissure or mineral vein, and thus dividing it.

RIFLES. *Rifled Ordnance* and *Fire-arms* are described under ARTILLERY and FIRE-ARMS.

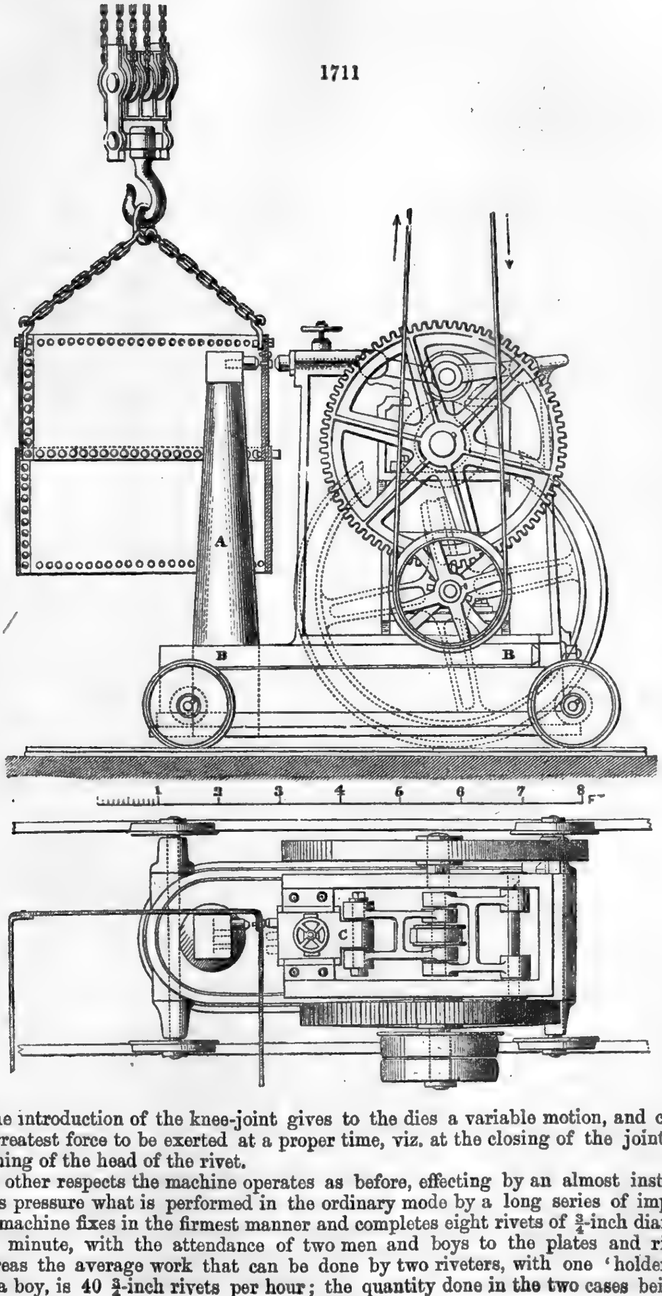
RINMANN'S GREEN. Oxide of cobalt and oxide of zinc.

RIVETING MACHINE *of Fairbairn.* The invention of the riveting machine originated in a turn-out of the boiler-makers in the employ of that engineer about thirty years ago. On that occasion the attempt was made to rivet two plates together by compressing the red-hot rivet in the ordinary punching-press. The success of this experiment immediately led to the construction of the original machine, in which the moveable die was forced upon the rivet by a powerful lever acted upon by a cam. A short experience proved the original machine inadequate to the numerous requirements of the boiler-maker's trade, and the present form was therefore adopted some years afterwards.

The large stem A (*fig.* 1711) is made of malleable iron, and having an iron strap, B B, screwed round the base, it renders the whole perfectly safe in case of the dies coming in contact with a cold rivet, or any other hard substance during the process. Its construction also allows the workmen to rivet angle-iron along the edges, and to finish the corners of boilers, tanks, and cisterns; and the stem being now made 4 feet 6 inches high, it renders the machine more extensive in its application, and allows of its riveting the fire-box of a locomotive boiler or any other work within the given depth.

In addition to these parts, it has a broad moving slide, C, in which are three dies corresponding with others in the wrought-iron stem. By using the centre die, every description of flat and circular work can be riveted, and by selecting those on the sides, it will rivet the corners, and thus complete vessels of almost every shape. This machine is in a portable form, and can be moved off rails with care to suit the article suspended from the shears.

1711



The introduction of the knee-joint gives to the dies a variable motion, and causes the greatest force to be exerted at a proper time, viz. at the closing of the joint and finishing of the head of the rivet.

In other respects the machine operates as before, effecting by an almost instantaneous pressure what is performed in the ordinary mode by a long series of impacts. The machine fixes in the firmest manner and completes eight rivets of $\frac{3}{4}$-inch diameter in a minute, with the attendance of two men and boys to the plates and rivets; whereas the average work that can be done by two riveters, with one 'holder on' and a boy, is 40 $\frac{3}{4}$-inch rivets per hour; the quantity done in the two cases being in the proportion of 40 to 480, or as 1 to 12, exclusive of the saving of one man's labour. The cylinder of an ordinary locomotive-engine boiler 8 feet 6 inches long and 3 feet diameter can be riveted and the plates fitted completely by the machine in 4 hours; whilst to execute the same work by hand would require with an extra man 20 hours. The work produced by the machine is likewise of a superior kind to that made in the ordinary manner; the rivets being found stronger, and the boilers more free from leakage, and more perfect in every respect. The riveting is done without noise, and thus is almost entirely removed the constant deafening clamour of the boiler-maker's hammer.

ROAN. The name of a common leather used for book-binding, and for slippers. It is prepared from sheep-skin by tanning with sumach. See LEATHER.

ROASTING ORES. The operation of roasting is executed by various processes, relatively to the nature of the ores, the quality of the fuel, and to the object in view.

Three principal methods may be distinguished: 1, the roasting in heaps in the open air, the most simple of the whole; 2, the roasting executed between little walls, and which may be called case-roasting (*Röst-stadel* in German); and 3, roasting in furnaces.

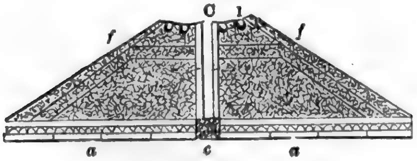
1. The roasting in the open air, and in heaps more or less considerable, is practised upon iron ores, and such as are pyritous or bituminous. The operation consists in general in spreading over the plane area, often bottomed with beaten clay, billets of wood arranged like the bars of a gridiron, and sometimes laid crosswise over one another, so as to form a uniform flat bed. Sometimes wood-charcoal is added, so as to fill up the interstices, and to prevent the ore from falling between the other pieces of fuel. Coal is also employed in moderately small lumps; and even occasionally turf. The ore, either simply broken into pieces, or sometimes under the form of *schlich* (fine pyritous sand), is piled up over the fuel; usually alternate beds of fuel and ore are formed.

The fire, kindled in general at the lower part, but sometimes, however, at the middle, gradually spreads, putting the operation in train. The combustion must be so conducted as to be slow and suffocated, to prolong the ustulation, and let the whole mass be equably penetrated with heat. The means employed to direct the fire, are to cover outwardly with earth the portions where too much activity is displayed, and to pierce with holes or to give air to those where it is imperfectly developed. Rains, winds, variable seasons, and especially good primary arrangements of a calcination, have much influence on this process, which requires besides an almost incessant inspection at the beginning.

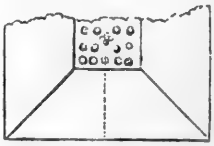
It may be laid down as a good rule, to employ no more fuel than is strictly necessary for the kind of calcination in hand, and for supporting the combustion; for an excess of fuel would produce, besides an expense uselessly incurred, the inconvenience, at times very serious, of such a heat as may melt or vitrify the ores: a result entirely the reverse of a well-conducted ustulation.

Figs. 1712, 1713, 1714, represent the roasting in mounds, as practised near Goslar in the Hartz, and at Chessy in the Department of the Rhône. *Fig.* 1712 is a vertical section, in the line *h c*, of *fig.* 1714. In *fig.* 1713 there is shown in plan, only a little more than one-half of the quadrangular truncated pyramid, which constitutes the heap. *Fig.* 1714 shows a little more than one-fourth of a bed of wood, arranged at the bottom of the pyramid, as shown by *a a*, *fig.* 1712, and *c g h*, *fig.* 1714. c is a wooden chimney, formed within the heap of ore, at whose bottom, *c*, there is a little parcel of charcoal; *d d* are large lumps of ore distributed upon the wooden pile *a a*; *e e* are smaller fragments to cover the larger; *f f* is rubbish and clay laid smoothly in a slope over the whole. *g*, *fig.* 1714, a passage for air left under the bed of billets, of which there is a smaller one in each of the four sides of the base *a a*, so that two principal currents of air cross under the upright axis *c c*, of the truncated pyramid indicated in *fig.* 1712.

1712

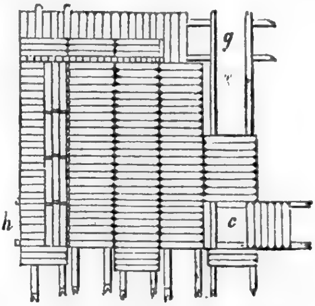


1713



Burning wood is thrown in by the chimney c. The charcoal and the wood take fire; the sulphurous ores, *d e f*, are heated to such a high temperature as to vaporise the sulphur. In the Lower Hartz, a heap of this kind continues roasting during four months

1714



2. The second method. The difficulty of managing the fire in the roasting of substances containing little sulphur, with the greater difficulty of arranging and supporting in their place the fine ores to be roasted, and last of all, the necessity of giving successive fires to the same ores, or to inconsiderable quantities at a time, have led to the contrivance of surrounding the area on which the roasting takes place with three or four little walls, leaving a door in the one in front. This is what is called a *walled area*, and sometimes, improperly enough, a roasting-furnace. Inside of these walls, about 3 feet high, there are often vertical conduits or chimneys made to correspond with an opening on the ground level, in order to excite a draught of air in the adjacent parts. When the roasting is once set going, these chimneys can be opened or shut at their upper ends, according to the necessities of the process.

Several such furnaces are usually erected in connection with each other by their lateral walls, and all terminated by a common wall, which forms their posterior part; sometimes they are covered with a shed supported partly by the back wall, built sufficiently high for this purpose. These dispositions are suitable for the roasting of *schlichs*, or pyritic sands, and in general of all matters which are to have several fires; a circumstance indispensable to a due separation of the sulphur, arsenic, &c.

3. The furnaces employed for roasting the ores and *mattes* differ much, according to the nature of the ores, and the size of the lumps. We shall content ourselves with referring to the principal forms.

When iron ores are to be roasted, which require but a simple calcination to disengage the combined water and carbonic acid, egg-shaped furnaces, similar to those in which limestone is burned in contact with fuel, may be conveniently employed; and they present the advantage of an operation which is continuous with a never-cooling apparatus. See Iron.

It has been attempted to employ the same method a little modified, for the roasting of ores of sulphide of copper and pyrites, with a view of extracting a part of the sulphur. More or less success has ensued, but without ever surmounting all the obstacles arising from the great fusibility of the sulphide of iron. For it sometimes runs into one mass, or at least into lumps agglutinated together in certain parts of the furnace, and the operation is either altogether stopped, or becomes more or less languid; the air not being able to penetrate into all the parts, the roasting becomes consequently imperfect. This inconvenience is even more serious than might at first sight appear; for, as the ill-roasted ores now contain too little sulphur to support their combustion, and as they sometimes fall into small fragments in the cooling, they cannot be passed again through the same furnace, and it becomes necessary to finish the roasting in a reverberatory hearth, which is much more expensive.

In the Pyrenees, the roasting of iron ores is executed in a circular furnace, so disposed that the fuel is contained and burned in a kind of interior oven, above which lie the pieces of ore to be calcined. Sometimes the vault of this oven which sustains the ore, is formed of bricks, leaving between them openings for the passage of the flame and smoke, and the apparatus then resembles certain pottery-kilns: at other times the vault is formed of large lumps of ore, carefully arranged as to the intervals requisite to be left for draught over the arch. The broken ore is then distributed above this arch, care being taken to place the larger pieces undermost. This process is simple in the construction of the furnace, and economical, as branches of trees, without value in the forests, may be employed in the roasting. See Kiln.

In some other countries, the ores are roasted in furnaces very like those in which porcelain is baked; that is to say, the fuel is placed exteriorly to the body of the furnace in a kind of brick shafts, and the flame traverses the broken ore with which the furnace is filled. In such an apparatus the calcination is continuous.

When it is proposed to extract the sulphur from iron pyrites, or from pyritous minerals, different furnaces may be employed, among which that used in Hungary deserves notice. It is a rectangular parallelopiped of four walls, each of them being perforated with holes and vertical conduits which lead into chambers of condensation, where the sulphur is collected. The ore placed between the four walls on billets of wood arranged as in *fig.* 1714, for the great roastings in the open air, is calcined with the disengagement of much sulphur, which finds more facility in escaping by the lateral conduits in the walls, than up through the whole mass, or across the upper surface covered over with earth; whence it passes into the chambers of condensation. In this way upwards of a thousand tons of pyrites may be roasted at once, and a large quantity of sulphur obtained. See PYRITES.

The reverberatory furnace affords one of the best means of ustulation where it is requisite to employ the simultaneous action of heat and atmospheric air to destroy certain combinations, and to decompose the sulphides, arsenides, &c. See COPPER.

In every case where it is desired to have a very perfect roasting, as for blende from which zinc is to be extracted, for sulphide of antimony, &c., or even for ores reduced to a very fine powder and destined for amalgamation, it is proper to perform the operation in a reverberatory furnace. When very fusible sulphurous ores are treated, the workmen charged with the calcination must employ much care and experience, chiefly in the management of the fire. It will sometimes, indeed, happen that the ore partially fuses, when it becomes necessary to withdraw the materials from the furnace, to let them cool and grind them anew, in order to recommence the operation. The construction of these furnaces demands no other attention than to give to the sole or laboratory the suitable size, and so to proportion to this the grate and chimney that the heating may be effected with the greatest economy.

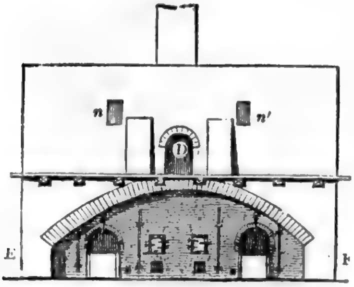
The reverberatory furnace is always employed to roast ores of the precious metals, and especially those for amalgamation; as the latter often contain arsenic, antimony, and other volatile substances, they must be disposed of in a peculiar manner.

The sole, usually very spacious, is divided into two parts, of which the one farthest off from the furnace is a little lower than the other. Above the vault there is a space or chamber in which the ore is deposited, and which communicates with the laboratory by a vertical passage, which serves to allow the ore to be pushed down when it is dried and a little heated. The flame and the smoke which escape from the sole or laboratory pass into condensing chambers before entering into the chimney, so as to deposit in them the oxide of arsenic and other substances. When the ore on the part of the sole farthest from the grate has suffered so much heat as to begin to be roasted, has become less fusible, and when the roasting of that in the nearer part of the sole is completed, the former is raked towards the fire-bridge, and its ustulation finished by stirring it over frequently with a paddle, skilfully worked, through one of the doors left in the side for this purpose. The operation is considered to be finished when the vapours and the smell have almost wholly ceased; its duration depending obviously on the nature of the ores.

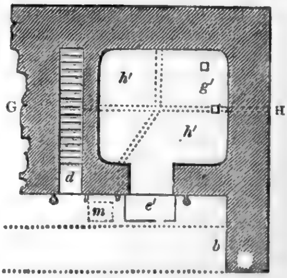
When this furnace is employed to roast very arsenical ores, the chambers of condensation for the arsenious acid are much more extensive than in furnaces commonly used.

Compared with the German *Röstöfen*, the mechanical furnaces are less efficient for the calcination of silver ores, particularly when the ores operated on are very damp and contain much sulphur; in which case the excessive production of lumps becomes a serious inconvenience to contend with.

1715



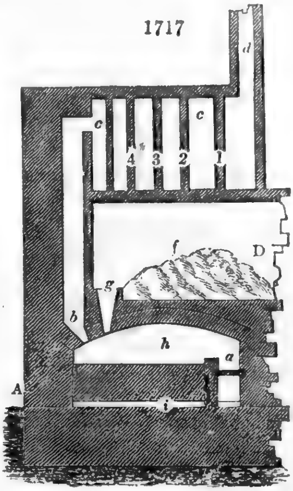
1716



But in the treatment of the silver ores of Hiendelaencina, they possess the advantage of calcining a large quantity of ore in a given time, and require no further attendance than is necessary for supplying them with ore and fuel. The supply of fuel is, however, subject to great neglect. The management of the fires is nevertheless a matter of much importance, for should they be forgotten, and the heat get much reduced, the mineral, from continuing to pass at the same rate through the furnace, cannot be properly calcined.

To prevent the fires getting low, and to raise them after being neglected, the workmen often load the grate with fuel, the result of which is to overheat the ore and cause a great waste of wood.

1717



Figs. 1715, 1716, and 1717 represent a reverberatory furnace employed in the smelting works of Lautenthal, in the Hartz, for roasting the *schlichs* of lead ores, which contain much blende or sulphide of zinc. In *fig.* 1715 we see that the two sides, are absolutely like, the two furnaces being built in one body of brickwork. *Fig.* 1716 is the plan of the furnace B C, taken at the level E F of *fig.* 1715. *Fig.* 1717 is a vertical section of the similar furnace A B, taken in the prolongation of the line G H in *fig.* 1716.

a is the fireplace of the furnace, its grate, and ash-pit. *b* is the conduit of vaporisation, which communicates with the chambers *c*; into which the vaporised substances are deposited; *d*, chimney for the escape of the smoke of the fireplace *a*, after it has gone through the space *b c c*; *e′* is the charging door, with a hook hanging in front to rest the long iron rake upon, with which the materials are turned over; *f*, chamber containing a quantity of *schlich* destined for roasting; this chamber communicates with the vaulted corridor (gallery) D, seen in *fig.* 1715; *g*, orifice through which the *schlich* is thrown into the furnace; *h*, area or hearth of the reverberatory furnace, of which the roof is certainly much too high; *i*, channels for the escape of the watery vapours; *k l*, front arcade, between which and the furnace, properly speaking, are the two orifices of the conduits, which terminate at the channels *m m′*. *m* is the channel for carrying towards the chimney, *d*, the vapours which escape by the door *e′*. *n* is a walled-up door, which is opened from time to time, to take out of the chambers *c*, *c*, the substances that may be deposited in them.

At the smelting-works of Lautenthal, in such a roasting-furnace, from 6 to 9 quintals (cwts.) of *schlich* are treated at a time, and it is stirred frequently with an iron rake upon the altar *h*. The period of this operation is from 6 to 12 hours, according as the *schlich* may be more or less dry, more or less rich in lead, or more or less charged with blende. When the latter substance is abundant, the process requires 12 hours, with about 60 cubic feet of cleft billets for fuel.

In such furnaces are roasted the cobalt ores of Schneeberg in Saxony, the tin ores of Schlackenwald in Bohemia, of Ehrenfriedersdorf in Saxony, and elsewhere; as also the arsenical pyrites at Geyer in Saxony. But there are poison towers and extensive condensing chambers attached in the latter case.

For a description of Gerstenhöfer's furnace for roasting metallic sulphides, see Copper.

ROCCELLA, from the Italian *rocca*, 'a rock;' a genus of lichens. See Archil; Lichens.

ROCCELLIC ACID. A fatty acid obtained from the *Roccella tinctoria.*

ROCHELLE SALT. A double tartrate of soda and potash: mixed with some carbonate of soda, and an equivalent of tartaric acid being added, after the salt is dissolved, it forms the artificial seidlitz-water.

ROCH or **ROCK ALUM.** A factitious article consisting of crystalline fragments of alum not larger than almonds, coloured with Venetian red. See Alum.

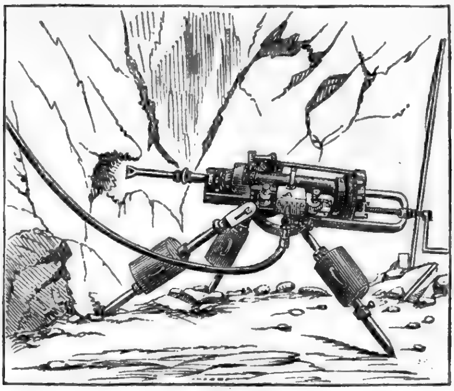
ROCK. A term used in South Staffordshire by miners to denote any hard sandstone.

ROCK CRYSTAL. A very fine transparent and colourless variety of quartz.

ROCK-DRILL or **PERFORATOR.** The rock-drill invented by Mr. Ingersol has achieved a high reputation in the mines of America. It has been introduced to this country by Messrs. Le Gros and Silva, and having excited much attention must be briefly described.

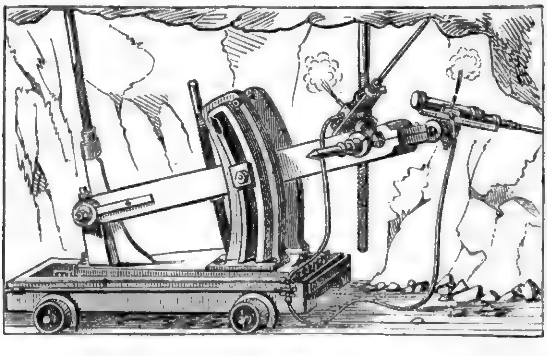
The chief principles and characteristic features of this rock-drill are, that the motive pressure is continued until the stroke of the piston takes effect in a blow on the rock (in lieu of being cut off at a point antecedent to the rock being struck), whereby an important accession of speed in penetration is attained; and that the feed or forward motion of the machine is strictly and completely automatic, dependent solely upon, and proceeding *pari passu* with, the actual work done, so that however variable may be the hardness of the rock on which it is operating, the piston acts on the feed-motion only when and so long as adequate penetration has been effected, thereby conducing to rapid and regular drilling, and steady progress and work. It appears to be an economical and effective machine, for all the operations of quarrying and mining, for rock excavations and removal by blasting, for shafts, sewerage works, tunnels, driftways, headings, &c., in mines, quarries, and various other engineering and constructive works. It may be worked by steam or compressed air, and so mounted as to drift bore-holes horizontally, vertically, or at any required angle. For example, as shown in the engravings, the ordinary tripod form (*fig.* 1718) is suitable for ordinary vertical drilling, and for boring holes in very narrow and irregular places, driftways, &c.; for railway tunnels, and the heavier class of operations, a car is employed with several drills mounted thereon (*fig.* 1719); and, again, *fig.* 1720 shows the ordinary form of 'gadding car,' designed for boring horizontal as well as vertical holes, to enable blocks of stone of any desired dimensions to be taken out of a quarry.

1718



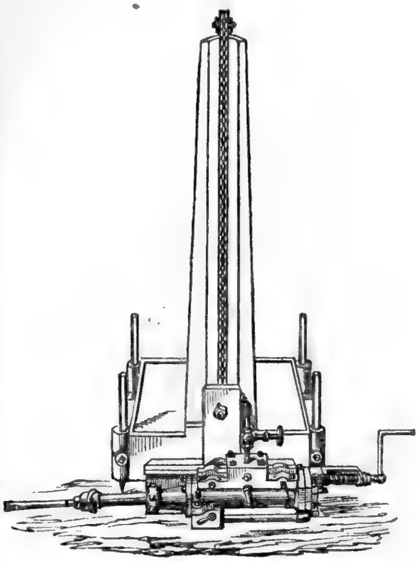
The mechanical construction and details are as follow:—It is one of the class of machines known as a percussive rock-drill, comprising a cylinder with a double-action reciprocating and rotating piston, with a piston-rod terminating at its outer extremity in a drilling or cutting tool. The drill-bar is raised by the upward pressure of the expansive fluid employed, upon the piston, and falls on that being withdrawn, the impulse of the downward stroke being aided and intensified by the expansive pressure when admitted, in alternation, to act upon the upper side of the piston; this in case of vertical downward drilling; in horizontal and overhead drilling, the weight of the piston, rod, and drill-bar is overcome, and the tool propelled against the rock to be bored, like a projectile from a gun, by the expansive force employed. The reciprocating motion of the piston itself is the automatic agent in effecting the alternate opening of the ports and the change of steam, induction, and eduction. Attached to the cylinder is a steam-chest and common D slide-valve, actuated by two short valve-stems, one at each end, which are worked by tappets having rounded shoulders, projecting into the cylinder, and so situated that the piston strikes against them at the completion of its stroke in either direction; on contact with either of the tappets, the piston thus not only effects a suitable change of steam by means of the valves, but at the same time restores the other tappet, at the opposite end, to its due projecting posi-

1719



tion, so that it may be acted upon at the return stroke. At each change the steam is admitted to the same end of the cylinder as the piston and the tappet struck, and, there being a sufficient clearance allowed, rushes in to cushion the piston and arrest and reverse the motion.

1720



The self-acting feed-motion, whereby the penetration of the rock, resulting from the rapid succession of blows, is mechanically accompanied by a corresponding advance in the boring machine itself, is actuated by means of another tappet, attached to the opposite side of the cylinder, so as to project into the cylinder at a point in the lower clearance below the valve-tappet and fitted with a spring for returning it into position after being struck; this feed-tappet is carried on to the external spindle, extending the opposite or upper end of the cylinder, and there acting by means of a pawl upon a ratchet-wheel or collar, attached to the cylinder so as to work round the feed-screw; and the action of this device is such that the feed is exactly proportioned to the progress of the work. If from excessive hardness or any other cause, the blow is ineffective, and the penetration deficient, *i.e.*, less than the distance between the valve and feed-tappets, or $\frac{3}{16}$ths of an inch, the piston fails to actuate the feed-motion, and the cylinder remains stationary for the time. It will readily be understood that the cylinder is fitted so as to slide in the frame, which is a semi-cylindrical shell, provided with V-shaped projections fitting into external grooves on the cylinder; the feed-screw is attached by a collar to the curved arm or bar on the head of the frame, and has a square head on which a winch-handle fits, whereby, when the cylinder has been fed forwards by the ratchet-and-pawl motion to the end of the guides or slides, it may be brought back by hand, ready for further operations, for which a longer drill-bar would have to be attached.

There remains to be noted another speciality in the mechanism, viz., the device whereby the necessary continuous, step-by-step, and partial rotation of the drill-rod, and piston is effected at each return stroke. This is effected by a peculiar rifling arrangement, which is brought to bear upon the interior and upper part of the piston and rod. For this purpose a suitably-rifled round steel-bar is attached by a collar to the top cylinder cover, and provided with a ratchet and pawls, so that it is free to rotate in one direction only; this bar has eight spiral grooves, one complete turn in 7 feet being the pitch, and projects downward into a corresponding hole bored in the piston and rod, which are fitted with a brag-nut fitted thereto, and rifled to correspond. By this means the rifled-bar and the piston and drill-bar are alternately made to make $\frac{1}{12}$th of a complete revolution at each stroke; on the down-stroke of the piston, which is straight, the rifled-bar is caused partially to rotate; but as it cannot go back on the upstroke, the piston takes the rifling and rotates partially in its turn; and the stroke and pitch are so proportioned that one entire revolution is made in about twelve complete strokes.

The smallest size of these rock-drills has a 2½-inch cylinder, and weighs only 173 lbs. (cylinder 123 lbs.); its piston-stroke is 3¼ inches, and it is capable of boring holes from ⅜-inch to 1¾-inch diameter to 10 feet deep, averaging, in the hardest crystalline trap-rock, about 35 feet linear of 1-inch bore-hole in a day of ten hours. In the largest size, weighing 818 lbs. (cylinder 558 lbs.), 5-inches cylinder, the stroke is variable, 8 inches for soft, and 5½ inches for hard rock. The drill-holes may be from 1¾ to 5 inches, and to a depth of 40 feet. With this machine a day's work of ten hours would average 25 feet of 3¾-inches bore-hole in the hardest trap. The small size delivers 800, and the large one 400 blows per minute.

ROCKETS. See PYROTECHNY.

ROCK FAT. See ADIPOCERE.

ROCK OIL. A name for petroleum. See NAPHTHA; PARAFFINE; PETROLEUM.

ROCK SALT. See Salt.

ROE STONE. A name for *oolite*, from its being like the roe of fish. See Oolite.

ROLLERS, ELASTIC, for printing. See Printing Rollers.

ROLLING MILLS. These useful aids to many of our metallurgical processes appear to have been introduced to this country in the seventeenth century; but it was not until 1784, when Mr. Cort patented 'a new mode and art of shingling, welding, and manufacturing iron and steel into bars, plates, &c.,' that much attention was directed to the value of the rolling mill.

1721

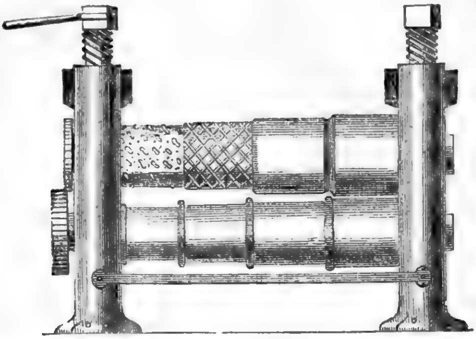
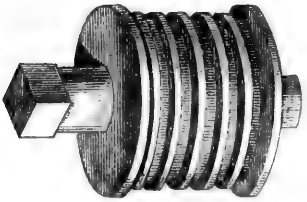


Fig. 1721 is a front view of a pair of rollers, used in the manufacture of iron in connection with the puddling furnace. They are about 4 feet long, divided into four parts, the largest being about 20 inches in diameter. The portion of the upper roller under which the metal is first passed, is cut in a deep and irregular manner, resembling that chiselling in stone called 'mosaique-work,' that it may the more easily get hold of and compress the metal when almost in a fluid state. The plate is next passed under the cross-cut portion of the roller, and successively through the flat sections. The lower roller, it will be observed, is formed with raised collars at intervals, to keep the metal in its proper course. The rollers are connected by cog-wheels placed upon their axes; upon the lowermost of these, works also the wheel by means of which the revolution is communicated. The cheeks are of cast iron, very massive, that they may bear the violent usage to which they are subjected.

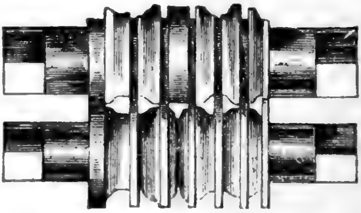
We cannot go into the numerous purposes to which rolling mills of this kind are applied; a few may however be mentioned.

The practice of 'slitting' sheets of metal into light rods, either for the use of the wire-drawers or of nail-makers, is carried out by means of two large steel rollers, channelled circularly, as in *fig.* 1722. These are so placed that the cutters or raised parts of one roller, which are exactly turned for that purpose, shall work in corresponding channels of the other roller, thus forming what may be called revolving shears, for the principle is that of clipping; so that a sheet of metal on being passed through this machinery, is separated into slips agreeing in size with the divisions of the rollers.

1722



1723



For the manufacture of rails, rolling mills are also employed, *fig.* 1723 representing a rolling mill as constructed for rolling Birkinshaw's rails. The open spaces along the middle of the figure, and which owe their figure to the moulding on the periphery of the rollers, indicate the form assumed by the iron rail as it is passed successively from the larger to the smaller apertures, till it is finished at the last.

For a further description, and for the arrangement of rolling mills and slitters, see Iron. Beyond these few notices the character of this Dictionary will not admit of our going; the reader is therefore referred to the works which have been published on the Metallurgy of Iron and Steel, for further information.

Rolling mills have been patented for rolling tubes for gas and other purposes. See Tubes.

ROMAN ALUM. An alum extracted from the volcanic rocks of the Solfatara; it contains more alumina than the common alum. See ALUM.

ROMAN CEMENTS. Under the name of Roman cement, some hydraulic mortars, varying considerably in their chemical composition, though physically possessing the same general character, are sold. Like all the hydraulic cements, it is an argillaceous lime. It is usually manufactured from a dark brown stone—a carbonate of lime with much alumina—found in the Island of Sheppy. This stone is calcined and mixed with a certain proportion of sand.

Any hydraulic limestone, that is, one containing from 15 to 20 per cent. of clay, will, when properly prepared, form this cement. Calcine any ordinary clay, and mix it with two-thirds its quantity of lime, grind to powder and calcine again; this makes a very beautiful cement, improperly called Roman, since the preparation was entirely unknown to the Romans. See HYDRAULIC CEMENT.

ROMAN OCHRE. A deep and powerful orange-yellow colour, transparent and durable. It is used both raw and burnt by artists. The colouring-matter is oxide of iron mixed with earthy matter. See OCHRE.

ROMAN VITRIOL. See COPPER.

ROOFING, ASPHALTE. Patent asphalte roofing felt, particularly applicable for warm climates. It is a non-conductor. It is portable, being packed in rolls, and not being liable to damage in carriage, it effects a saving of half the timber usually required. It can be easily applied by any unpractised person. From its lightness, weighing only about 42 lbs. to the square of 100 feet, the cost of cartage is small. The felt can be laid on from gable to gable, or across the roof from eaves to eaves. It is essential that it should be stretched tight and smooth, overlapping full one inch at the joinings, and closely nailed through the overlap with twopenny fine clout nails (heated in a shovel and thrown when hot into grease to prevent rust), about 1½ inch apart, but copper nails are preferable.

The whole roof must have a good coating of coal-tar and lime (about two gallons of the former to six pounds of the latter), well boiled together, kept constantly stirring while boiling, and put on hot with a common tar mop, and while it is soft, some coarse sharp sand may be sifted over it. The coating must be renewed every fourth or fifth year, or more or less frequently according to the climate. The gutters should be made of two folds, one over the other, cemented together with the boiling mixture.

ROOFING-SLATE. See SLATE.

ROPE-MAKING. The fibres of hemp which compose a rope seldom exceed in length 3½ feet at an average. They must, therefore, be twined together so as to unite them into one; and this union is effected by the mutual circumtorsion of the two fibres. If the compression thereby produced be too great, the strength of the fibres at the points where they join will be diminished; so that it becomes a matter of great consequence to give them only such a degree of twist as is essential to their union.

The first part of the process of rope-making by hand, is that of spinning the yarns, or threads, which is done in a manner analogous to that of ordinary spinning. The spinner carries a bundle of dressed hemp round his waist; the two ends of the bundle being assembled in front. Having drawn out a proper number of fibres with his hand, he twists them with his fingers, and fixing this twisted part to the hook of a whirl, which is driven by a wheel put in motion by an assistant, he walks backwards down the rope-walk, the twisted part always serving to draw out more fibres from the bundle round his waist, as in the flax spinning-wheel. The spinner takes care that these fibres are equally supplied, and that they always enter the twisted parts by their ends, and never by their middle. As soon as he has reached the termination of the walk, a second spinner takes the yarn off the whirl, and gives it to another person to put upon a reel, while he himself attaches his own hemp to the whirl-hook, and proceeds down the walk. When the person at the reel begins to turn, the first spinner, who has completed his yarn, holds it firmly at the end, and advances slowly up the walk, while the reel is turning, keeping it equally tight all the way, till he reaches the reel, where he waits till the second spinner takes his yarn off the whirl-hook, and joins it to the end of that of the first spinner, in order that it may follow it on the reel.

The next part of the process is that of warping the yarns, or stretching them all to one length, which is about 200 fathoms in full-length rope-grounds, and also in putting a slight turn or twist into them.

The third process in rope-making is the tarring of the yarn. Sometimes the yarns are made to wind off one reel, and, having passed through a vessel of hot tar, are wound upon another, the superfluous tar being removed by causing the yarn to pass through a hole surrounded with spongy oakum; but the ordinary method is to tar it in skeins or hanks, which are drawn by a capstan with a uniform motion through the tar-kettle. Yarn for cables requires more tar than for hawser-laid ropes; and for standing and running rigging, it requires to be merely well covered. Tarred cordage has been found to be weaker than what is untarred, when it is new; but the tarred rope is not so easily injured by immersion in water.

The last part of the process of rope-making is to lay the cordage. For this purpose two or more yarns are attached at one end to a hook. The hook is then turned the contrary way from the twist of the individual yarn, and thus forms what is called a strand. Three strands, sometimes four, besides a central one, are then stretched at length, and attached at one end to three contiguous but separate hooks, but at the other end to a single hook; and the process of combining them together, which is effected by turning the single hook in a direction contrary to that of the other three, consists in so regulating the progress of the twists of the strands round their common axis, that the three strands receive separately at their opposite ends just as much twist as is taken out of them, by their twisting the contrary way, in the process of combination.

Large ropes are distinguished into the *cable-laid* and the *hawser-laid*. The former are composed of nine strands, namely, three great strands, each of these consisting of three smaller secondary strands, which are individually formed with an equal number of primitive yarns. A *cable-laid* rope, 8 inches in circumference, is made up of 333 yarns, or threads, equally divided among the nine secondary strands. A *hawser-laid* rope consists of only three strands, each composed of a number of primitive yarns, proportioned to the size of the rope; for example, if it be 8 inches in circumference, it may have 414 yarns, equally divided among three strands. Thirty fathoms of yarn are reckoned equivalent in length to 18 fathoms of rope cable-laid, and to 20 fathoms hawser-laid. Ropes of from 1 inch to 2½ inches in circumference are usually hawser-laid; of from 3 to 10 inches, are either hawser- or cable-laid; but when more than 10 inches, they are always cable-laid.

Every hand-spinner in the dockyard is required to spin, out of the best hemp, six threads, each 160 fathoms long, for a quarter of a day's work. A hawl of yarn, in the warping process, contains 336 threads.

The following are Captain Huddart's improved principles of the rope manufacture:—

1. To keep the yarns separate from each other, and to draw them from bobbins revolving upon skewers, so as to maintain the twist while the strand, or primary cord, is forming.

2. To pass them through a register, which divides them by circular shells of holes; the number in each concave shell being conformable to the distance from the centre of the strand, and the angle which the yarns make with a line parallel to it, and which gives them a proper position to enter.

3. To employ a tube for compressing the strand, and preserving the cylindrical figure of its surface.

4. To use a gauge for determining the angle which the yarns in the outside shell make with a line parallel to the centre of the strand, when registering; because, according to the angle made by the yarns in this shell, the relative lengths of all the yarns in the strand will be determined.

5. To harden up the strand, and thereby increase the angle in the outside shell; which compensates for the stretching of the yarns, and the compression of the strands.

The improvements in the manufacture of cordage at present in use either in Her Majesty's yards or in private rope-grounds, owe their superiority over the old method of making cordage to Captain Huddart's invention of the register-plate and tube.

Captain Huddart invented and took a patent for a machine, which, by registering the strand at a short length from the tube, and winding it up as made, preserved an uniformity of twist, or angle of formation, from end to end of the rope, which cannot be accomplished by the method of forming the strands down the ground, where the twist is communicated from one end to the other of an elastic body upwards of 300 yards in length. This registering-machine was constructed with such correctness, that when some were afterwards required, no alteration could be made with advantage.

A number of yarns cannot be put together in a cold state, without considerable vacancies, into which water may gain admission; Captain Huddart, therefore, formed the yarns into a strand immediately as they came from the tar-kettle, which he was enabled to do by his registering-machine, and the result was most satisfactory. This combination of yarns was found by experiment to be 14 per cent. stronger than the cold register; it constituted a body of hemp and tar impervious to water, and had great advantage over any other cordage, particularly for shrouds, as, after they were settled on the mast-head, and properly set up, they had scarcely any tendency to stretch, effectually secured the mast, and enabled the ship to carry the greatest press of sail.

In order more effectually to obtain correctness in the formation of cables and large cordage, Captain Huddart constructed a laying machine, which has carried his inventions in rope-making to the greatest perfection, and which, founded on true mathematical principles, and the most laborious calculations, is one of the noblest monuments of mechanical ability since the improvement of the steam-engine by Watt. By this machine, the strands receive that degree of twist only which is necessary, and are laid at any angle with the greatest regularity; the pressure is regulated to give the required elasticity, and all parts of the rope are made to bear equally.

The following description of one of the best modern machines for making ropes on Captain Huddart's plan, may be useful to the reader:—

1724

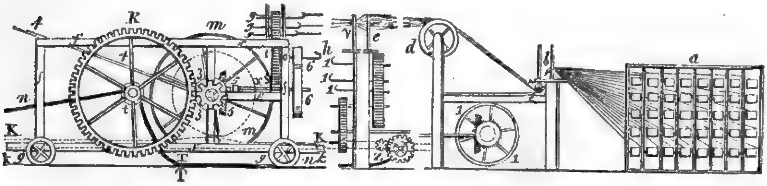


Fig. 1724 exhibits a side elevation of the tackle-board and bobbin-frame at the head of the ropery, and also of the carriage or rope-machine in the act of hauling-out and twisting the strands.

Fig. 1725 is a front elevation of the carriage.

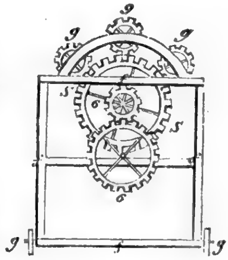
Fig. 1726 is a yarn-guide, or board, or plate, with perforated holes for the yarns to pass through before entering the nipper.

Figs. 1727 and 1728 are side and front views of the nipper for pressing the rope-yarns.

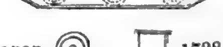
a is the frame for containing the yarn-bobbins. The yarns are brought from the frame, and pass through a yarn-guide at *b*. *c* is a small roller, under which the rope-yarns pass; they are then brought over the reel *d*, and through another yarn-guide *e*, after which they enter the nippers at *v*, and are drawn out and formed into strands by the carriage. The roller and reel may be made to traverse up and down, so as to regulate the motion of the yarns.

The carriage runs on a railway. *f*, *f*, is the frame of the carriage; *g*, *g*, are the small wheels on which it is supported; *k*, *k*, is an endless rope reaching from the head to the bottom of the railway, and is driven by a steam-engine; *m*, *m*, is a wheel with gubs at the back of it, over which the endless rope passes, and gives motion to the machinery of the carriage. *n* is the ground-rope for taking out the carriage, as will be afterwards described. On the shaft of *m*, *m*, are two bevel-wheels, 3, 3, with a shifting catch between them; these bevel-wheels are loose upon the shaft, but when the catch is put into either of them, this last then keeps motion with the shaft, while the other runs loose. One of these wheels serves to communicate the twist to the strand in drawing out; the other gives the opposite or after-turn to the rope in closing. 4, 4, is a lever for shifting the catch accordingly. 5 is a third bevel-wheel, which receives its motion from either of the other two, and communicates the same to the two spur-wheels 6, 6, by means of the shaft *x*. These can be shifted at pleasure; so that by applying wheels of a greater or less number of teeth above and beneath, the twist given to the strands can be increased or diminished accordingly. The upper of these two communicates motion, by means of the shaft *o*, to another spur-wheel 8, which working in the three pinions above, 9, 9, gives the twist to the strand-hooks. The carriage is drawn out in the following manner:—On the end of the shaft of *m*, *m*, is the pinion 3, which, working in the large wheel R, gives motion to the ground-rope shaft upon its axis. In the centre of this shaft is a curved pulley or drum *t*, round which the ground-rope takes one turn. This rope is fixed at the head and foot of the

1725



1726



1727

1728

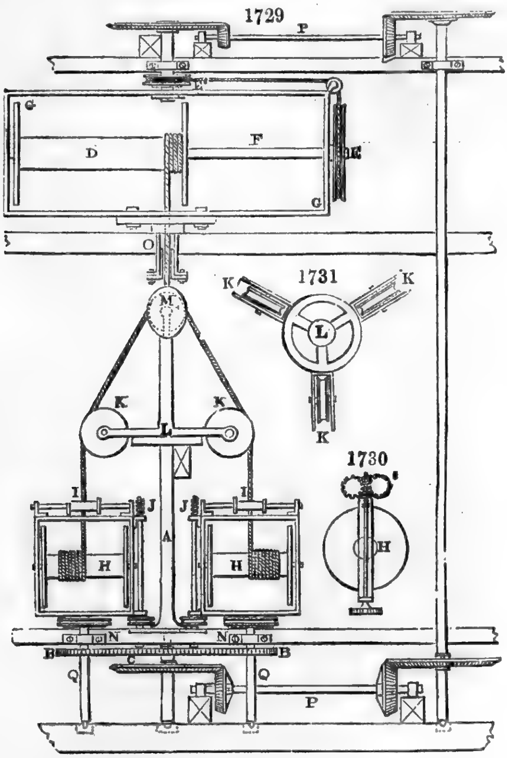
ropery, so that when the machinery of the carriage is set agoing by the endless rope, *k*, *k*, and gives motion to the ground-rope shaft, as above described, the carriage will necessarily move along the railway; and the speed may be regulated either by the diameter of the circle formed by the gubs on the wheel *m*, *m*, or by the number of teeth in the pinion 3. At T, is a small roller, merely for preventing the ground-rope from coming up among the machinery. At the head of the railway, and under the tackle-board, is a wheel and pinion Z, with a crank for tightening the ground-rope. The fixed machinery at the head, for hardening or tempering the strands, is similar to that on the carriage, with the exception of the ground-rope gear, which is unnecessary. The motion is communicated by another endless rope (or short band, as it is called, to distinguish it from the other), which passes over gubs at the back of the wheel 1, 1.

When the strands are drawn out by the carriage to the requisite length, the spur-wheels 3, R, are put out of gear. The strands are cut at the tackle-board, and fixed to the hooks 1, 1, 1; after which they are hardened or tempered, being twisted at both ends. When this operation is finished, three strands are united on the large hook *h*, the top put in, and the rope finished in the usual way.

In preparing the hemp for spinning an ordinary thread- or rope-yarn, it is only heckled over a large keg or clearer, until the fibres are straightened and separated, so as to run freely in the spinning. In this case the hemp is not stripped of the tow, or cropped, unless it is designed to spin beneath the usual grist, which is about 20 yarns for the strand of a 3-inch strap-laid rope. The spinning is still performed by hand, being found not only to be more economical, but also to make a smoother thread than has yet been effected by machinery. Various ways have been tried for preparing the yarns for tarring. That which seems now to be most generally in use is, to warp the yarns upon the stretch as they are spun. This is accomplished by having a wheel at the foot, as well as the head of the walk, so that the men are able to spin both up and down, and also to splice their threads at both ends. By this means they are formed into a haul, resembling the warp of a common web, and a little turn is hove into the haul, to preserve it from getting foul in the tarring. The advantages of warping from the spinners, as above, instead of winding on winches, as formerly, are, 1st, the saving of this last operation altogether; 2ndly, the complete check which the foreman has of the quantity of yarn spun in the day; 3rdly, that the quality of the work can be subjected to the minutest inspection at any time. In tarring the yarn, it is found favourable to the fairness of the strip, to allow it to pass around or under a reel or roller in the bottom of the kettle while boiling, instead of coiling the yarn in by hand. The tar is then pressed from the yarn, by means of a sliding nipper, with a lever over the upper part, and to the end of which the necessary weight is suspended. The usual proportion of tar in ordinary ropes is something less than a fifth. In large strap-laid ropes, which are necessarily subjected to a greater press in the laying of them, the quantity of tar can scarcely exceed a sixth, without injuring the appearance of the rope when laid.

For a long period the manner of laying the yarns into ropes was by stretching the haul on the rope-ground, parting the number of yarns required for each strand, and twisting the strands at both ends, by means of hand-hooks, or cranks. It will be obvious that this method, especially in ropes of any considerable size, is attended with serious disadvantages. The strand must always be very uneven; but the principal disadvantage, and that which gave rise to the many attempts at improvement, was, that the yarns being all of the same length before being twisted, it followed, when the rope was finished, that while those which occupied the circumference of the strand were perfectly tight, the centre yarns, on the other hand, as they were now greatly slackened by the operation of hardening or twisting the strands, actually would bear little or no part of the strain when the rope was stretched, until the former gave way. The method displayed in the preceding figures and description is among the most improved processes. Every yarn is given out from the bobbin-frame as it is required in twisting the rope; and the twist communicated in the out-going of the carriage can be increased or diminished at pleasure. In order to obtain a smooth and well-filled strand, it is necessary also, in passing the yarns through the upper board, to proportion the number of centre to that of outside yarns. In ordinary-sized ropes, the strand seems to have the fairest appearance when the outside yarns form from two-thirds to three-fourths of the whole quantity, in the portion of twist given by the carriage in drawing out and forming the strands.

In laying cables, torsion must be given both behind and before the laying-top. *Figs.* 1729 to 1732 represent the powerful patent apparatus employed for this purpose. A, is a strong upright iron pillar, supported upon the great horizontal beam N, N, and bearing at its upper end the three-grooved laying-top M. H, H, are two of the three great bobbins or reels round which the three secondary strands or small hawsers are wound. These are drawn up by the rotation of the three feeding rollers I, I, I, thence proceed over the three guide-pulleys K, K, K, towards the laying-top M, and finally pass through the tube O, to be wound upon the cable-reel D. The frames of the three bobbins H, H, H, do not revolve about the fast pillar A, as a common axis; but each bobbin revolves round its own shaft Q, which is steadied by a bracing collet at N, and a conical step at its bottom. The three bobbins are placed at an angle of 120 degrees apart, and each receives a rotatory motion upon its axis from the toothed spur-wheel B, which is driven by the common central spur-wheel C. Thus each of the three secondary cords has a proper degree of twist put into it in one direction, while the cable is laid, by getting a suitable degree of twist in an opposite direction, from the revolution of the frame or cage G, G, round two pivots, the one under the pulley E, and the other over O. The reel D has thus, like the bobbins H, H, two movements; that in common with its frame, and that upon its axis, produced by the action of the endless band round the pulley E, upon one of its ends, and the pulley E′ above its centre of rotation. The pulley E is driven by the bevel mill-gearing P, P, P, as also the under spur-wheel C. L, in *fig.* 1729, is the place of the ring L, *fig.* 1731, which bears the three guide-pulleys K, K, K. *Fig.* 1734 is an end view of the bobbin H, to show the worm or endless screw J, of *fig.* 1729 working into the two snail-toothed wheels, upon the ends of the two feed-rollers I, I, which serve to turn them. The upright shafts of J, J, receive their motion from pulleys and cords near their bottom. Instead of these pulleys, and the others, E E′, bevel-wheel gearing has been substituted with advantage, not being liable to slip, like the pulley-band mechanism. The axis of the great reel is made twice the length of the bobbin D, in order to allow of the latter moving from right to left, and back again alternately, in winding on the cable with uniformity as it is laid. The traverse mechanism of this part is, for the sake of perspicuity, suppressed in the figure.



1729

1731

1730

Mr. William Norvell, of Newcastle, obtained a patent for an improvement adapted to the ordinary machines employed for twisting hempen yarns into strands, affording, it is said, a simpler and more eligible mode of accomplishing that object, and also of laying the strands together, than had been theretofore effected by machinery.

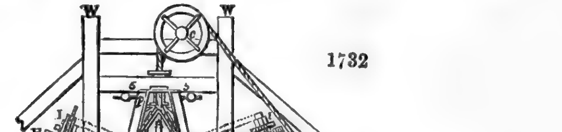
His improvements consisted, first, in the application of three or more tubes, two of which are shown in *fig.* 1732, placed in inclined positions, so as to receive the strands immediately above the press-block *a*, *a*, and nearly in a line with A, the point of closing or laying the rope. B^1 and B^3 are opposite side views; B^2, an edge view; and B, a side section of the same. He did not claim any exclusive right of patent for the tubes themselves, but only for their form and angular position.

Secondly, in attaching two common flat sheaves, or pulleys, C, C, *fig.* 1732, to each of the said tubes, nearly round which each strand is lapped or coiled, to prevent it from slipping, as shown in the section B^1. The said sheaves or pulleys are connected by a crown or centre-wheel, D, loose upon *b*, *b*, the main or upright axle; E, E, is a smaller wheel upon each tube, working into the said crown or centre-wheel, and fixed upon the loose box I, on each of the tubes.

F, F, is a toothed or spur-wheel, fixed also upon each of the loose boxes I, and working into a smaller wheel, G, upon the axis 2 of each tube; H is a bevel-wheel fixed upon the same axis with G, and working into another bevel-wheel, *j*, fixed upon the cross axle 3 of each tube; K is a spur-wheel attached to the same axis with *j*, at the opposite end, and working into L, another spur-wheel of the same size upon each of the tubes. By wheels thus arranged and connected with the sheaves or pulleys, as above described, a perfectly equal strain or tension is put upon each strand as drawn forward over the pulley C.

Thirdly, the invention consists in the introduction of change-wheels, M, M, M, M, *fig.* 1732, for putting the forehard or proper twist into each strand before the rope is laid; this is effected by small spindles on axles, 4, 4, placed parallel with the line of each tube B.

Upon the lower end of each spindle the bevel-wheels N, N, are attached, and driven by other bevel-wheels, O, O, fixed immediately above each press-block, *a*, *a*. On the top end of each spindle or axle, 4, 4, is attached one of the change-wheels, working into the other change-wheel fixed upon the bottom end of each of the tubes, whereby the forehard, or proper twist in the strands for all sizes of ropes, is at once attained, by simply changing the sizes of those two last-described wheels, which can be very readily effected, from the manner in which they are attached to the tubes B, B, and 4, 4.


1732

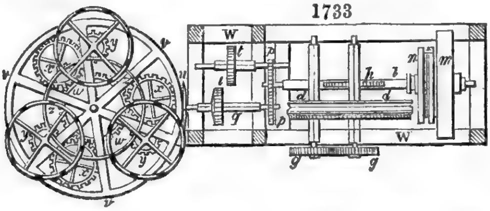
From the angular position of the tubes towards the centre, the strands are nearly in contact at their upper ends, where the rope is laid, immediately below which the forehard or proper twist is given to the strands.

Fourthly, in the application of a press-block, P, of metal, in two parts, placed directly above and close down to where the rope is laid at A, the insdie of which is polished, and the under end is bell-mouthed; to prevent the rope from being chafed in entering it, a sufficient grip or pressure is put upon the rope by one or two levers and weights, 5, 5, acting upon the press-block, so as to adjust any trifling irregularity in the strand or in the laying; the inside of which, being polished, gives smoothness, and by the said levers and weights, a proper tension to the rope, as it is drawn forward through the press-block. By the application of this block, ropes may be made at once properly stretched, rendering them decidedly preferable and extremely advantageous particularly for shipping, inclined planes, mines, &c.

The preceding description includes the whole of Mr. Norvell's improvements; the remaining parts of the machine may be briefly described as follow:—A wheel or pulley, *c*, is fixed independently of the machine, over which the rope passes to the drawing motion represented at the side; *d*, *d*, is a grooved wheel, round which the rope is passed, and pressed into the groove by means of the lever and weight *e*, *e*, acting upon the binding-sheaf *f*, to prevent the rope from slipping. After the rope leaves the said sheaf, it is coiled away at pleasure. *g*, *g*, are two change-wheels, for varying the speed of the grooved wheel *d*, *d*, to answer the various sizes of ropes; *h*, is a spiral wheel, driven by the screw *k*, fixed upon the axle *l*; *m* is a band-wheel, which is driven by a belt from the shaft of the engine, or any other communicating power; *n*, *n*, is a friction-strap and striking-clutch. The axle *q* is driven by two change-wheels *p*, *p*; by changing the sizes of those wheels, the different speeds of the drum R, R, for any sizes of ropes, are at once effected.

The additional axle *s*, and wheels *t*, *t*, shown in *fig.* 1733, are applied occasionally for reversing the motion of the said drums, and making what is usually termed left-hand ropes; *u*, *figs.* 1732, 1733, shows a bevelled pinion, driving the main crown-wheel *v*, *v*, which wheel carries and gives motion to the drums R, R; *w*, *w*, is a fixed or sun-wheel, which gives a reverse motion to the drums, as they revolve round the same, by means of the intervening wheels *x*, *x*, *x*, whereby the reverse or retrograding motion is produced, which gives to the strands the right twist. The various retrograding motion or right twist for all sizes and descriptions of ropes, may be obtained by changing the diameters of the pinions *y*, *y*, *y*, on the under ends of the drum spindles; the carriages of the intervening wheels *x*, *x*, *x*, being made to slide round the ring *z*, *z*; W, W, is the framework of the machine and drawing motion; T, T, T, are the bobbins containing the yarns; their number is varied to correspond with the different sizes of the machine.

1733



Messrs. Chapman, of Newcastle, having observed that rope-yarn is weakened by passing through the tar-kettle, that tarred cordage loses its strength progressively in cold climates, and so rapidly in hot climates as to be scarcely fit for use in three years, discovered that the deterioration was due to the reaction of the mucilage and acid of the tar. They accordingly proposed the following means of amelioration: 1. Boiling the tar with water, in order to remove these two soluble constituents. 2. Concentrating the washed tar by heat, till it becomes pitchy, and then restoring the plasticity which it thereby loses, by the addition of tallow, or animal or expressed oils.

The same engineers patented a method of making a belt or flat band, of two, three, or more strands of shroud or hawser-laid rope, placed side by side, so as to form a band of any desired breadth, which may be used for hoisting the kibbles and corves in mine-shafts, without any risk of its losing twist by rotation. The ropes should be laid with the twist of the one strand directed to the right hand, that of the other to the left, and that of the yarns the opposite way to the strands, whereby perfect flatness is secured to the band. This parallel assemblage of strands has been found also to be stronger than when they are all twisted into one cylinder. The patentees at the same time contrived a mechanism for piercing the strands transversely, in order to brace them firmly together with twine. Flat ropes are usually formed of hawsers with three strands, softly laid, each containing thirty-three yarns, which with four ropes compose a cordage 4½ inches broad and 1¼ inch thick, being the ordinary dimensions of the grooves in the whim-pulleys round which they pass.

Relative Strength of Cordage, shroud-laid.

Size	Warm register				Cold register				Common staple			
	tons	cwts.	qrs.	lbs.	tons	cwts.	qrs.	lbs.	tons	cwts.	qrs.	lbs.
3 inches bore .	3	17	...	16	3	5	3	16	2	9	1	24
3½ " .	5	5	...	...	4	9	2	21	3	6	1	27
4 " .	6	17	...	16	5	17	...	4	4	5	3	7
4½ " .	8	13	2	8	7	5	3	1	5	1	2	6
5 " .	10	14	1	4	9	3	...	4	6	9	2	8
5½ " .	12	19	2	4	11	1	1	25	7	12	...	22
6 " .	14	15	2	24	13	3	2	8	8	17	1	20
6½ " .	18	2	...	10	15	9	1	9	9	16	3	14
7 " .	21	...	...	...	17	18	3	8	11	4	1	21
7½ " .	24	2	...	16	20	11	3	9	12	8	3	6
8 " .	27	8	1	26	23	8	2	8	13	2	3	12

The above statement is the result of several hundred experiments.

ROPE, WIRE. See Wire Rope.

ROSANILINE. The name given by Dr. Hofmann to a compound which plays the part of a well-defined base in the formation of the aniline reds. It may now be considered as demonstrated that the aniline reds are salts of a peculiar and extremely remarkable compound, called *rosaniline*. See Aniline.

Rosaniline in the anhydrous state is represented by the formula $C^{40}H^{19}N^{3}$ ($\mathbf{C^{20}H^{19}N^{3}}$), and in the hydrated state, such as it assumes when isolated from its compounds, by the formula $C^{40}H^{19}N^{3}.2HO$ ($\mathbf{C^{20}H^{19}N^{3}.H^{2}O}$).

It is a triamine capable of combining with one, two, and three equivalents of acid. The pure aniline reds are saline compounds of rosaniline with one equivalent of acid.

It is very interesting that rosaniline itself, when freshly prepared, is a colourless compound. It is nearly insoluble in water, slightly soluble in ammonia, more soluble in ether. When exposed to the action of the air, rosaniline becomes rapidly rose-coloured, and finally of a deep red, probably in consequence of the formation of a carbonate. It is a rather powerful base, forming salts, almost all of which are remarkable for their beauty, and the facility with which they crystallise.

The salts containing one equivalent of acid exhibit, for the most part, in reflected light, the lustrous metallic green of the wings of the rose-beetle; in transmitted light the crystals are red, becoming opaque when they acquire certain dimensions. The solutions of these salts in water or alcohol possess the magnificent crimson colour which characterises rosaniline-compounds. According to M. Chevreul, who, in the extensive course of his memorable researches on the theory of dyeing, examined the colouring-matters derived from coal-tar, the green colour reflected from the salts of rosaniline is exactly complementary to the colour which these salts impart to wool or silk.

The salts with three equivalents of the stronger acids, on the other hand, are yellowish-brown, both in the solid state and in solution. They are much more soluble in water and alcohol than the monacid salts, which, for the most part, are comparatively sparingly soluble.

Both classes of rosaniline salts crystallise readily, more especially the monacid compounds, some of which Mr. Nicholson has obtained in perfectly well-formed crystals.

The formula of rosaniline has been corroborated by the examination and analysis of its salts, the most important of which are the following:—

Hydrochlorate.—Prepared either by the action of hydrochloric acid, or of chloride of ammonium, upon the free base, the monacid salt is deposited from its boiling solution in well-defined rhombic plates, frequently in stellar forms. This chloride is difficultly soluble in water, more soluble in alcohol, and insoluble in ether.

The salt retains a little water at 100° C., but becomes anhydrous at 130° C.

Like most of the rosaniline salts, this salt is very hygroscopic. The monacid chloride dissolves more readily in moderately strong hydrochloric acid than in water. If this solution, gently warmed, be mixed with very concentrated hydrochloric acid, it solidifies on cooling into a network of beautiful brown-red needles, which have to be washed with concentrated hydrochloric acid and dried *in vacuo* over sulphuric acid and lime, since water decomposes them with reproduction of the monacid compound. The salt obtained by the action of concentrated hydrochloric acid is a compound with three equivalents of acid.

Exposed to 100° C., this salt gradually loses acid, the brown crystals becoming indigo-blue; and if the exposure be continued until the weight becomes constant, the original green-salt with one equivalent of acid is reproduced.

Sulphate of Rosaniline is readily obtained by dissolving the free base in boiling dilute sulphuric acid. On cooling, the salt is deposited in green metal lustrous crystals, which by one recrystallisation become perfectly pure.

Acetate of Rosaniline.—This is probably the finest salt of the series. Mr. Nicholson obtained it in crystals an inch in diameter, which, on analysis, were found to be the pure monacid acetate. The crystals of this salt, when freshly prepared, exhibit in a marked manner a beautifully green metallic lustre; on protracted exposure to the light this lustre disappears, and the crystals assume a dark reddish-brown tint.

The acetate is one of the more soluble salts both in water and in alcohol; on a smaller scale it cannot be conveniently recrystallised.

Nitrate of Rosaniline is easily formed by dissolving the base in warm dilute nitric acid. On cooling, the salt crystallises in small crystals resembling the other salts of rosaniline.

Of the remaining salts of this base we may mention the *chromate*, which is obtained by adding chromate of potash to a solution of the acetate, in the form of a brick-red precipitate, becoming a green crystalline, almost insoluble, powder on ebullition with water.

The *Tannates of Rosaniline*, described by M. E. Kopp, are also very beautiful salts; they are true carmine lakes which rival the renowned carmine-lake obtained from cochineal. They are entirely insoluble in water, bnt soluble in alcohol, wood-spirit, and acetic acid. In the dry state they do not present the green metallic appearance of the other salts of rosaniline, but preserve their beautiful carmine-red colour.

The tannate of rosaniline is of considerable importance to industry, not only because it is formed in nearly all the cotton fabrics dyed and printed in red or rose with rosaniline, but also because, by reason of its insolubility, it enables the manufacturer to make use of very dilute aqueous solutions of aniline red, which are often obtained in the factories during the purification of rosaniline. In fact, the best manner of treating these solutions, which are too poor in colouring-matter to be advantageously employed in any other way, consists in precipitating them with a fresh solution of nut-galls; after a very short time all the rosaniline is precipitated in a state of magnificent red lake, the mother-liquors becoming almost entirely colourless.

Iodide of Rosaniline.—Hobrecker, of Crefeld, discovered a violet colouring-matter, derived from rosaniline, which crystallises easily, and is characterised by its rich reddish tone. This colouring-matter is obtained by the action of a mixture of chloride of benzyl and iodide of methyl upon rosaniline, dissolved in methylic alcohol. The mixture is digested for some time in a water-bath. As the deep violet solution cools, needles of a green metallic lustre separate out, and can be obtained completely pure by re-solution in alcohol and re-crystallisation. The compound—an iodide—is almost insoluble in water, sparingly soluble in cold alcohol, but more soluble in the same liquid when hot. The iodide, dried at 100° C., was analysed by Hofmann, with the following results:—Carbon, 70·56; hydrogen, 6·0; nitrogen, 5·89; iodine, 17·67: total, 100·12.

ROSEINE. See Aniline Red.

ROSELET. The fur of the ermine *Mustela erminea*, as it is taken from the animal in the summer. See Ermine.

ROSEMARY. The *Rosmarinus officinale* contains a volatile oil, and is used in perfumery.

ROSENSTIEHL'S GREEN, known also as *Cassel green*. This is a *baryta* green, or a *manganate of baryta*. The best mode of preparing it is as follows, according to M. E. Fleischer:—On precipitating a green boiling solution of manganate of potash with chloride of barium, there is formed a deposit strongly granular, but not crystalline. This precipitate is of a violet colour, bordering on blue. It is well washed by decantation, and then filtered. When dried, its colour becomes paler as the temperature rises. At a dark red heat it is white, with a slight greyish-blue tinge. If heated higher, with access of air, it becomes by degrees completely green, then of a fine blue, and at very elevated temperatures it is converted into a dirty brown-grey. If a solution of permanganate of potash is precipitated with chloride of barium, and allowed to boil, there is slowly formed a reddish-violet deposit (colour of peach-blossom), and the liquid retains an intense violet colour. The precipitate may be washed by decantation, and filtered without decomposition. It can even be dried at 100° without losing its colour. When gradually heated, the permanganate of baryta loses its colour, like the manganate, but at very high temperatures it behaves differently. When its colour has once been destroyed by a moderate heat, it does not become either green or blue by farther heating with access of air. The whole becomes at once of a greyish-brown. The finest barytes green is formed by calcining the manganate of baryta. Rosenstiehl's process—the fusion of hydrate of baryta with chlorate of potash and peroxide of manganese—yields an inferior colour.

ROSE OIL. See OTTO OF ROSES.

ROSE-PINK. A coarse and common colour, much used in the cheaper kinds of paper-staining, and for distemper painting. It is prepared by saturating chalk with a strong infusion of Brazil-wood.

ROSETTA WOOD. An East-Indian wood of a lively red-orange colour, and handsomely veined with darker marks. It is occasionally used in fine cabinet-work.

ROSEWOOD. This well-known wood, which has long been fashionable for drawing-room and library furniture, is a native of the Brazils, the East Indies, the Canary Islands, and some parts of Africa. The best rosewood comes from Rio de Janeiro, and is believed to be yielded by a species of *Dalbergia.*

'Rosewood is a term as generally applied as iron-wood, and to as great a variety of plants in different countries, sometimes from the colour, and sometimes from the smell of the woods. The rosewood of Bahia and Rio Janeiro, called also Jacaranda, is so named, according to Prince Maximilian, as quoted by Dr. Lindley, because when fresh it has a faint but agreeable smell of roses, and is produced by a mimosa in the forests of Brazil. Mr. G. Loddiges informs me it is the *Mimosa jacaranda.*'—*Holtzapffel.*

Rosewood is imported in large slabs, or the halves of trees, some of these logs producing as much as 150*l.* when cut into veneers.

ROSIN, or *common resin.* The residue of the process for obtaining oil of turpentine. While liquid it is run into metallic receivers coated with whiting to prevent adhesion, and from these laded into casks. See TURPENTINE.

Rosin imported in 1873.

	Cwts.	Value
From France	61,793	£32,954
,, United States of America . .	888,025	434,085
,, Other countries	5,971	4,569
Total	955,789	471,608

Rosin imported in 1874, 1,066,681 cwts.; value 442,700*l.*

When the distillation is not carried too far, the product is called *yellow rosin*; it then contains a little water. The heat being continued, the water is expelled, and *transparent rosin* is the result.

If the process be continued up to a point short of producing the decomposition of the rosin, it acquires a deep colour, and becomes *brown* or *black* rosin, sometimes called *colophony.*

Rosin is insoluble in water, but soluble in alcohol, ether, and the volatile oils. It unites with wax and the fixed oils by heat, forming the *Emplastrum rosinæ* of the London Pharmacopœia.

Rosin is employed in common varnishes; it is united with tallow in the preparation of common candles. It has been proposed to employ rosin as a source from which gas might be obtained. The experiments made were not, however, of so successful a kind as to warrant the general adoption of the process.

ROSIN OIL. By distillation rosin separates into rosin oil and tar. (See TAR.) This oil is a mixture of four carbides of hydrogen: $C^{14}H^{8}$; $C^{10}H^{12}$; $C^{32}H^{16}$; and $C^{20}H^{8}$. The rosin oil, which distils over at about 300° Fahr., is sometimes used in the arts as a substitute for the oil of turpentine. The part which boils at 464° Fahr., called *retinole,* $C^{32}H^{16}$, enters into the composition of some printing inks.

ROSIN TIN. A pale-coloured oxide of tin with a resinous lustre is so called by the miner.

ROSOLANE. See ANILINE VIOLET.

ROSOLIC ACID, discovered by Rungé, and more fully examined by Hugo Müller. Obtained by exhausting the crude carbonate of lime from the gas-purifiers with a dilute boiling solution of carbonate of ammonia; evaporating to dryness, ammonia is evolved, and a dark resinous body separates, which is the crude rosolic acid. The crude acid thus obtained is purified by conversion into a lime salt, and the acid is again liberated by acetic acid.

ROTCH, or **ROCHE.** A local term used by quarrymen and miners in South Staffordshire for a soft and friable sandstone.—H.W.B.

ROTTEN-STONE. A polishing-powder which is much used for giving lustre to brass, silver, and even to glass surfaces. According to the analysis of Richard Philips, the rotten-stone of Ashford in Derbyshire consists of, carbon, 10; alumina, 86·0; silica, 4·0. Rotten-stone is nearly peculiar to this country, being found principally in Derbyshire, near Bakewell, and in Carmarthenshire and Breconshire, South Wales.

It is thought by geologists to be derived in Derbyshire from the siliceous limestone, 'the lime being decomposed, and the silex remaining as a light earthy mass.' This does not, however, agree with the above analysis, in which alumina occupies so large a proportion. The total annual produce of the country is under 300 tons.

ROUGE. (*Fard*, Fr.) A cosmetic employed to brighten a lady's complexion. See Carmine.

ROUGE, JEWELLERS'. An oxide of iron prepared with much care. See Oxides for Polishing.

ROUND ORE. *In Lead mining*, the largest pieces of lead ore selected free from the carbonate of lime or quartz, with which it may be associated in the lode.

ROWLEY RAG. A peculiar augitic trap, forming the chief portion of the Rowley Hills, near Dudley. Attempts have been made to fuse it, and then casting it into ornamental shapes in moulds, to use it for architectural purposes; but the experiments have not been successful.

ROYAL BLUE. (*Bleu de Roi*, Fr.) A fine deep blue prepared from cobalt, and used for enamel and porcelain painting.

The term *Bleu de Roi*, or *Royal Blue*, has of late been applied to one of the finest of the aniline blues.

RUBBLE. A local term used by quarrymen and miners for loose angular gravel, or a slightly-compacted brecciated sandstone.—H.W.B.

RUBIACIN. *Madder-orange; Krapp-orange.* A yellow colouring-matter discovered by Rungé. See Madder.

RUBIAN. A deep-yellow matter discovered by Schunk in madder. For the analogous substances to, and derivatives of, rubian, consult 'Dictionary of Chemistry,' by Watts. See Madder.

RUBICELLE. The yellow or orange-red varieties of spinel. See Ruby.

RUBIDIUM. (See also Cæsium and Thallium.) Prof. Bunsen, in examining, by means of the spectrum, the alkalis of a mineral spring at Dürkheim, in the Palatinate, noticed the appearance of some bright lines which he had not observed in any previous investigation of like kind; and, as he had, by well-established chemical methods, separated all the non-alkaline metals, he concluded that these lines must be caused by the presence of some new alkaline metal. Although he had obtained only $\frac{1}{15000}$ part of a gramme of the substance, he did not doubt the accuracy of his conclusion; so delicate and so reliable are the indications of the spectroscope. He resolved, therefore, to obtain for examination a larger quantity of the presumed new body; and, with this view, he proceeded at once to evaporate 40 tons of the mineral water. It soon became evident that *two* new alkalis were present; and from the 40 tons of water Bunsen succeeded in preparing about 7 grammes of the chloride of the one metal, and 9 grammes of the chloride of the other. To the first of these substances he gave the name of *Cæsium*, from *cæsius*, bluish-grey, on account of its spectrum being characterised by two bright blue lines. For the second he proposed the name *Rubidium*, from *rubidis*, dark red, because of the existence in its spectrum of two red bands. Cæsium and rubidium, in their chief chemical properties, closely resemble potassium; so closely indeed that their existence would probably have escaped notice, had it not been for the peculiarities which their spectra exhibit. For the purpose of separating the two new metals from sodium- and potassium-compounds, Bunsen took advantage of the fact that the chlorides of rubidium and cæsium form, with bichloride of platinum, double salts, much more sparingly soluble in water than the corresponding double salt. By washing the precipitate containing the platinum salts of rubidium, cæsium and potassium, the whole of the latter salt is easily removed. The absence of the well-known potassium line in the spectrum of the salt serves as a test to indicate the absolute purity of the new metals. It was, however, much more difficult to separate cæsium from rubidium, so closely do they resemble one another in their properties. But carbonate of cæsium was found to be soluble in alcohol, in which carbonate of rubidium, like the other alkaline carbonates, is insoluble. The metals thus isolated have been carefully studied by Bunsen; and small as were the quantities at his disposal, he soon succeeded in determining the composition, crystalline form, and general properties of many of their salts, besides establishing their numerical equivalents. Both metals form salts strictly isomorphous with the salts of potassium. The equivalent of rubidium, Rb, is 85·36; that of cæsium, Cs, 133. After the publication of the memoir on the new alkalis, M. Bunsen examined the water of a large number of German saline springs, and in almost all he found cæsium and rubidium in quantities more or less minute. The solid sources of rubidium are much more prolific; several varieties of lepidolite, in particular, containing it in notable proportions, so that from this mineral it may now be prepared by the pound. Dr. Struve, the well-known manufacturer of artificial mineral waters, is now selling (at six thalers per kilo.) the residue from the preparation of lithia, which residue contains about fifteen per cent. of chloride of rubidium. M. Grandeau of Paris tested many of the French mineral waters for the new metals, and with very frequent success. The waters of Bourbonnes-les-Bains, in particular, proved to be rich in rubidium and cæsium; ten litres of the water having yielded M. Grandeau no less than two grammes of the double chlorides of the new metals and platinum. M. Grandeau has likewise shown that rubidium occurs in the mother-liquor left after the extraction of the alkalis from beet-root *vinasses.* From one kilogramme of the mother-liquor M. Grandeau obtained no less than 4·7 grammes of chloride of rubidium, or exactly 0·47 per cent. Hence it appears that rubidium is a notable constituent of certain soils; so that the question arises whether the new alkalis take part, like potash and soda, in the nutrition of plants; and if so, whether as merely accidental or substitution constituents of ash, or (in certain cases) as essential ingredients thereof.—(*Hofmann.*) For the salts of rubidium, see Watts's 'Dictionary of Chemistry.'

RUBIRETINE. See MADDER.

RUBY. A beautiful and favourite gem. The true ruby is a red sapphire, an almost pure form of alumina. (See SAPPHIRE.) This extremely valuable gem is found chiefly in the kingdom of Ava, and is frequently known as *Oriental Ruby,* in order to distinguish it from the commoner stone called *Spinel Ruby.*

Ruby spinel, or *Spinel ruby,* is of a light or dark red, and, if held near the eye, a rose-red colour. Its hardness is 8; specific gravity 3·523. Its fundamental form is the cube or hexahedron, but it occurs crystallised in many secondary forms, such as octahedrons and tetrahedrons. Fracture conchoïdal; lustre vitreous; colour red, passing into blue and green, yellow, brown, and black; and sometimes it is nearly white. Pure spinel is a compound of alumina and magnesia, usually in the proportions of about 28 magnesia and 72 alumina, although we sometimes find the magnesia partially replaced by lime, and the alumina by oxide of iron. Vauquelin discovered 6·18 per cent. of chromic acid in the red spinel. The red varieties exposed to heat become black and opaque; on cooling, they appear first green, then almost colourless, but at last resume their red colour.

Pleonaste is a black variety which yields a deep green globule with borax.

Balas ruby. Pale red or rose-red spinel, with sometimes a tinge of brown or violet.

Rubicelle. Yellow or orange-coloured spinel.

Almandine ruby, which is of a violet-red colour.

Crystals of spinel from Ceylon have been observed embedded in limestone, mixed with mica, or in rocks containing adularia, which seem to have belonged to a primitive district. Other varieties, like the pleonaste, occur in the drusy cavities of rocks ejected by Vesuvius. Crystals of spinel are often found in diluvial and alluvial sand and gravel, along with true sapphires, pyramidal zircon, and other gems, as also with magnetic iron ore, in Ceylon. Blue and pearl grey varieties occur in Südermannland in Sweden, embedded in granular limestone. Pleonaste is met with also in the diluvial sands of Ceylon. Clear and finely-coloured specimens of spinel are highly prized as ornamental stones. When the weight of a good spinel exceeds 4 carats, it is said to be valued at half the price of a diamond of the same weight. M. Brard has seen one at Paris which weighed 215 grains. As a gem, the ruby is cut in the same form as the diamond, and may be set with a foil of copper or gold.

RUBY, ORIENTAL. The red sapphire. See RUBY.

RUBY SILVER. See PYRARGYRITE; SILVER.

RUBY, SPINEL. See RUBY.

RUE (*Ruta graveolens*) produces a yellow colouring-matter similar to that obtained from BUCKWHEAT, which see.

RUM is a variety of ardent spirits distilled in the West Indies from the fermented skimmings of the sugar-waste, mixed with molasses, and diluted with water to the proper degree. A sugar plantation in Jamaica or Antigua, which makes 200 hogsheads of sugar, of about 16 cwts. each, requires for the manufacture of its rum two copper-stills; one of 1,000 gallons for the wash, and one of 600 gallons for the low wines, with corresponding worm-refrigerators. It also requires two cisterns, one of 3,000 gallons for the lees or spent wash of former distillations, called dunder (*quasi redundar,* Span.), another for the skimmings of the clarifiers and teaches of the sugar-house, along with twelve or more fermenting cisterns or tuns.

Our *Importation* of Rum was as follows in 1873 :—

	Proof gallons	Value
		£
From Spanish West India Islands . .	621,597	55,803
,, Dutch ,, ,, . .	102	12
,, ,, Guiana	156,422	15,297
,, Mauritius.	390,350	31,112
,, Straits Settlements	2,063	101
,, British West India Islands . .	2,313,665	304,416
,, ,, Guiana.	3,341,847	325,222
,, Other countries	105,265	10,733
Total	6,931,311	742,696

Entered for home consumption . . 5,029,033 proof gallons
Gross amount received for duty . . £2,556,194

The wort is made, in Jamaica, by adding to 1,000 gallons of dunder, 120 gallons of molasses, 720 gallons of skimmings (=120 of molasses in sweetness), and 160 gallons of water; so that there may be in the liquid nearly 12 per cent. of solid sugar. The formula prescribes so much spent wash as would be apt to communicate an unpleasant flavour to the spirits. Both the fermenting and flavouring principles reside chiefly in the fresh cane-juice, and in the skimmings of the clarifier; because, after the syrup has been boiled, they are in a great measure dissipated.

The fermentation goes on most uniformly in very large masses, and requires from 9 to 15 days to complete; the difference of time depending upon the strength of the wort, the condition of its fermentable stuff, and the state of the weather. The progress of the attenuation of the wash should be examined from day to day with a hydrometer. When it has reached nearly to its *maximum*, the wash should be as soon as possible transferred by pumps into the still, and worked off by a properly-regulated heat; for if allowed to stand over, it will deteriorate by acetification.

About 115 gallons of proof rum are usually obtained from 1,200 gallons of wash. The proportion which the product of rum bears to that of sugar, in very rich, moist plantations, is rated, by Edwards, at 82 gallons of the former to 16 cwts. of the latter; but the more usual ratio is 200 gallons of rum to 3 hogsheads of sugar. But this proportion will necessarily vary with the value of rum and molasses in the market. In one considerable estate in the island of Grenada, 92 gallons of rum were made for every hogshead (16 cwts.) of sugar.

Rum is largely used in the Navy. Its general consumption will, however, be shown by the quantities imported, as given above.

The duty now fixed, if from British Possessions and from the country of its production (July 17, 1860), is 10*s.* 2*d.* per gallon; not from the country of production is 10*s.* 5*d.* per gallon. Rum Shrub is imported at the same rate of duties.

RUNNING-OUT-FIRE, *in metallurgy.* A name given to the refinery furnace. See Iron.

RUSH. A common plant, extensively employed in the manufacture of mats, baskets, &c. The Rush family—*Juncaceæ*—are natives of all parts of the world, though they belong chiefly to the colder regions. Under the equator they occur as alpine plants, while in the northern climates they are found in the marshes. Upwards of 100 species of rush are described. The long leaves of many of the species are used for tying plants in gardens, and for making the bottoms of chairs, mats, and the like. The central cellular tissue, or pith, is used for candles, called *Rushlights.* Bulrushes are a different plant (*Typha*); these are used for polishing wood, and also by coopers. The Dutch rush (*Equisetum hyemale*) is also much used for polishing metals and stone.

RUSSET. *Madder Brown* or *Field's Russet,* a pure rich transparent brown, prepared from the madder-root.

RUSSIAN LEATHER. See Leather, Russian.

RUST is the orange-yellow coat of peroxide which forms upon the surface of iron exposed to moist air. Oil, paint, varnish, plumbago, grease, or indeed any body which will shield the metal from the moist air, may be employed, according to circumstances, to prevent the rusting of iron utensils.

Iron under all ordinary circumstances effects the decomposition of water, abstracting the oxygen, and combining with it. The rusting of iron is one of the many instructive examples of chemical affinity which are constantly occurring around us.

The Messrs. Myers have patented a composition for preventing rust on bright steel, iron, brass, or other metal surfaces. For this purpose they take: Gutta-percha, 10 lbs.; mutton-suet, 20 lbs.; beef-suet, 30 lbs.; neats-foot oil, 2 gallons; rape oil, 1 gallon.

These materials are melted together until thoroughly dissolved, and then coloured with a small portion of rose-pink; oil of thyme, or other perfuming matter, being at the same time added. When cold, the composition is ready to be applied by rubbing upon the metallic surfaces which require protection.

RUTACEÆ. The only plant in this natural order which is employed in manufacture is the false Dittany (*Dictamnus fraxinella*). Perfumers obtain from the flowers of this shrub a very odorous distilled water, which is used as a cosmetic. It is also employed in giving flavour to some liqueurs.

RUTE, *in mining*. Used in some lead mines to distinguish very small strings of ore.

RUTHENIUM (*Symb.* Ru.; *At. wt.* 52·11). After osmium, ruthenium is the most refractory metal known. It requires a very extreme heat to melt the smallest quantity. When melting, there is formed the oxide of ruthenium, which is volatilised, and which smells something like osmic acid. When removed from the flame, ruthenium is blackish-brown on the surface, and is brittle and hard like iridium. It is only distinctly separated from this last metal by its density, which is obviously half that of iridium. The purest ruthenium obtained has a density of 11 to 11·4.

To prepare the metal mix the osmide in fine powder with 3 parts of binoxide of barium and 1 part of nitrate of baryta, and heat them to redness in a clay crucible for an hour. The black friable mass which remains is powdered with great care and introduced into a flask in which has been previously mixed 20 parts of water and 10 parts of ordinary muriatic acid. The flask must be placed in cold water to avoid the elevation of temperature which would ensue from the violent reaction which takes place. This operation should be conducted under a good chimney to avoid the escape of the osmic-acid vapour into the laboratory.

When this reaction is finished, 1 part nitric acid is added, and then 2 parts ordinary strong sulphuric acid. The flask is now well shaken, and the sulphate of baryta is allowed to deposit. The supernatant liquid is then poured off, the precipitate is washed by decantation, and the liquid and the washings are distilled together in a tubulated retort, until about a fourth of their volume of a liquid very rich in osmic acid has passed over. The red liquor which is left in the retort is evaporated to a small volume, 2 or 3 parts of sal-ammoniac in small pieces are added, and a small quantity of nitric acid. The whole is now evaporated to dryness at the temperature of boiling water. A crystalline violet-black precipitate remains in the capsule, which is treated with a small quantity of water partly saturated with sal-ammoniac, and washed with the same solution until it is no longer coloured. The insoluble salt left (chloroiridate of ammonia containing ruthenium) is heated by degrees to redness in a porcelain crucible. The mixture of iridium and ruthenium thus obtained is fused in a silver crucible with an equal weight of hydrated potash and twice its weight of nitre, and when cold the rutheniate of potash is dissolved out with cold water; the solution, which is yellow, is decomposed by means of carbonic or nitric acid, and the precipitated oxide of ruthenium is strongly calcined in a charcoal crucible. The ruthenium is then reduced in the apparatus before described. Iridium and ruthenium present many analogies; their coloured reactions are the same, and the oxide of iridium dissolves in a mixture of nitre and potash.

Ruthenium forms with zinc an alloy which will burn in the air; it crystallises in hexagonal prisms. With tin there is formed an alloy $RuSn^2$, which crystallises in cubes as beautiful in their form and lustre as crystallised bismuth.—*Deville and Debray on the Platinum Metals.*

RUTILE. Native oxide of titanium.

Rutile occurs in granite, gneiss, mica-slate, and Syenitic rocks, and occasionally in granular limestone. It has sometimes been met with in specular iron. The way in which it occurs in masses of quartz or felspar, the acicular crystals being imbedded, is very curious. The following localities are given by Dana: 'Brazil affords acicular crystals in limpid quartz; also occurs in Arendal in Norway; Sau-alpe, Carinthia; in the Urals; in the Tyrol; at St. Gotthard; at St. Yrieix, in France; Krummhennersdorf near Freiberg; in Castile, in geniculated crystals, often very large. At Ohlapian in Transylvania, *Nigrine* in pebbles; in large crystals in Perthshire; at Cairngorm, Scotland; at Craig Cailleach near Killin, and in Bengloe; in Isles of Burray, Shetland. A variety from Karingsbricka in Sweden contains a small percentage of chrome, and is the *titane oxydé chromifère* of Haüy. Rough octahedrons, reticulated within, from Brazil, are supposed to be pseudomorphs after anastase.' Besides these, Dana gives at least twenty localities in America.

The oxide of titanium is employed for a yellow colour, in painting porcelain; and it is often employed to give the requisite tint to artificial teeth. Rutile is so named from the Latin *rutilus*, which signifies 'a shining red.'

RYE (*Seigle*, Fr.; *Roggen*, Ger.) is a cereal grain (*Secale cereale*), supposed to be a native of Crete, and apparently used at a very early period by man. The culture of rye is confined to the temperate zones. Rye consists, according to the analysis of Einhof, of 24·2 of husk, 65·6 of flour, and 10·2 of water, in 100 parts. This chemist found in 100 parts of the flour, 61·07 of starch, 9·48 of gluten, 3·28 of vegetable albumen, 3·28 of uncrystallisable sugar, 11·09 of gum, 6·38 of vegetable fibre, and the loss was 5·62, including a vegetable acid not investigated. Some phosphate of lime and magnesia is also present.

Rye-straw has been long used and celebrated for the manufacture of straw-plait.

RYE, ERGOT OF. (*Secale cornutum*). The grain rye is subject to a disease (*Spermedia clavis*) commonly known as *ergot*, which causes the grain to turn black. It is produced by the attack of a fungus known as *Cordyceps purpurea*. The ergot is used medicinally. See Pereira's *Materia Medica*.

S

SABICA WOOD. A wood grown in Cuba, and used for ship-building. It is the produce of *Lysdonia Sabica*.

SABLE. A valuable fur obtained from the marten. See Fur.

SABOT. A wooden shoe. The manufacture of these in France is very important.

SABOTIÈRE. An apparatus for making ices; it is composed of two principal parts—a pail which is indented towards the top and covered, and the *sabótière*, or inner vessel, slightly conical, which is inserted in the pail, on which it rests by a projecting border or rim; this vessel is closed at the bottom like a cup, and open at the top to admit the creams to be iced. The freezing-mixture is turned into the pail, and the creams to be iced into the inner vessel; its cover is then fastened by the hook, and the vessel is set into the pail among the freezing liquid; then taking the whole by the handle of the sabotière, an alternate motion of rotation is given to it for about a quarter of an hour, when the cream is sufficiently frozen. See Freezing Mixture.

SACCHAROMETER is the name of a hydrometer, adapted by its scale to point out the proportion of sugar, or the saccharine matter of malt, contained in a solution of any specific gravity. Brewers, distillers, and the Excise, sometimes denote by the term 'gravity' the excess of weight of 1,000 parts of a liquid by volume above the weight of a like volume of distilled water, so that if the specific gravity be 1045, 1070, 1090, &c.; the gravity is said to be 45, 70, or 90; at others, they thereby denote the weight of saccharine matter in a barrel (36 gallons) of worts; and again, they denote the excess in weight of a barrel of worts over a barrel of water, equal to 36 gallons, or 360 pounds. This and the first statement are identical, only 1,000 is the standard in the first case, and 360 in the second.

The saccharometer used by the Excise, and by the trade, is that constructed by the late Mr. R. B. Bate. The instrument is composed of brass; the ball or float being a circular spindle, in the opposite ends of which are fixed a stem and a loop. The stem bears a scale of divisions, numbered downwards from the first to 30; these divisions, which are laid down in an original manner, observing a diminishing progression according to true principles; therefore each division correctly indicates the one-thousandth part of the specific gravity of water; and further, by the alteration made in the bulk of the saccharometer at every change of poise, each of the same divisions continues to indicate correctly the said one-thousandth part throughout.

The following Table shows the quantities of sugar contained in syrups of the annexed specific gravities. It was the result of experiments carefully made by the late Dr. Ure:—

Experimental spec. gravity of solution at 60° F.	Sugar in 100· by weight	Experimental spec. gravity of solution at 60° F.	Sugar in 100· by weight
1·3260	66·666	1·1045	25·000
1·2310	50·000	1·0905	21·740
1·1777	40·000	1·0820	20·000
1·4400	33·333	1·0635	16·666
1·1340	31·250	1·0500	12·500
1·1250	29·412	1·0395	10·000
1·1110	26·316		

Table exhibiting the Quantity of Sugar, in Pounds Avoirdupois, which is contained in One Gallon of Syrup, at successive Degrees of Density, at 60° F.

Specific gravity	lbs. per gallon	Extract by weight in 100·	Specific gravity	lbs. per gallon	Extract by weight in 100·	Specific gravity	lbs. per gallon	Specific gravity	lbs. per gallon
1·000	0·0000	·0000	1·077	2·0197	·1851	1·154	4·0880	1·231	6·1474
1·001	0·0255	·0026	1·078	2·0465	·1873	1·155	4·1148	1·232	6·1743
1·002	0·0510	·0051	1·079	2·0734	·1896	1·156	4·1319	1·233	6·2012
1·003	0·0765	·0077	1·080	2·1006	·1918	1·157	4·1588	1·234	6·2280
1·004	0·1020	·0102	1·081	2·1275	·1941	1·158	4·1857	1·235	6·2551
1·005	0·1275	·0128	1·082	2·1543	·1963	1·159	4·2128	1·236	6·2822
1·006	0·1530	·0153	1·083	2·1811	·1985	1·160	4·2502	1·237	6·3093
1·007	0·1785	·0179	1·084	2·2080	·2007	1·161	4·2771	1·238	6·3362
1·008	0·2040	·0204	1·085	1·2359	·2029	1·162	4·3040	1·239	6·3631
1·009	0·2295	·0230	1·086	2·2627	·2051	1·163	4·3309	1·240	6·3903
1·010	0·2550	·0255	1·087	2·2894	·2073	1·164	4·3578	1·241	6·4152
1·011	0·2805	·0280	1·088	2·3161	·2095	1·165	4·3847	1·242	6·4401
1·012	0·3060	·0306	1·089	2·3438	·2117	1·166	4·4115	1·243	6·4650
1·013	0·3315	·0331	1·090	2 3710	·2139	1·167	4·4383	1·244	6·4902
1·014	0·3570	·0356	1·091	2·3987	·2161	1·168	4·4652	1·245	6·5153
1·015	0·3825	·0381	1·092	2·4256	·2183	1·169	4·4923	1·246	6·5402
1·016	0·4180	·0406	1·093	2·4524	·2205	1·170	4·5201	1·247	6·5651
1·017	0·4335	·0431	1·094	2·4792	·2227	1·171	4·5460	1·248	6·5903
1·018	0·4590	·0456	1·095	2·5061	·2249	1·172	4·5722	1·249	6·6152
1·019	0·4845	·0481	1·096	2·5329	·2270	1·173	4·5983	1·250	6·6402
1·020	0·5100	·0506	1·097	2·5598	·2292	1·174	4·6242	1·251	6·6681
1·021	0·5351	·0531	1·098	2·5866	·2314	1·175	4·6505	1·252	6·6960
1·022	0·5602	·0555	1·099	2·6130	·2335	1·176	4·6764	1·253	6·7240
1·023	0·5853	·0580	1·100	2·6404	·2357	1·177	4·7023	1·254	6·7521
1·024	0·6104	·0605	1·101	2·6663	·2378	1·178	4·7281	1·255	6·7800
1·025	0·6355	·0629	1·102	2·6921	·2400	1·179	4·7539	1·256	6·8081
1·026	0·6606	·0654	1·103	2·7188	·2421	1·180	4·7802	1·257	6·8362
1·027	0·6857	·0678	1·104	2·7446	·2443	1·181	4·8051	1·258	6·8643
1·028	0·7108	·0703	1·105	2·7704	·2464	1·182	4·8303	1·259	6·8921
1·029	0·7359	·0727	1·106	2·7961	·2486	1·183	4·8554	1·260	6·9201
1·030	0·7610	·0752	1·107	2·8227	·2507	1·184	4·8802	1·261	6·9510
1·031	0·7861	·0776	1·108	2·8485	·2529	1·185	4·9051	1·262	6·9822
1·032	0·8112	·0800	1·109	2·8740	·2550	1·186	4·9300	1·263	7·0133
1·033	0·8363	·0825	1·110	2·9001	·2571	1·187	4·9552	1·264	7·0444
1·034	0·8614	·0849	1·111	2·9263	·2593	1·188	4·9803	1·265	7·0751
1·035	0·8866	·0873	1·112	2·9522	·2614	1·189	5·0054	1·266	7·1060
1·036	0·9149	·0897	1·113	2·9780	·2635	1·190	5·0304	1·267	7·1369
1·037	0·9449	·0921	1·114	3·0045	·2656	1·191	5·0563	1·268	7·1678
1·038	0·9768	·0945	1·115	3·0304	·2677	1·192	5·0822	1·269	7·1988
1·039	1·0090	·0969	1·116	3·0563	·2698	1·193	5·1080	1·270	7·2300
1·040	1·0400	·0993	1·117	3·0821	·2719	1·194	5·1341	1·271	7·2601
1·041	1·0653	·1017	1·118	3·1080	·2740	1·195	5·1602	1·272	7·2902
1·042	1·0906	·1041	1·119	3·1343	·2761	1·196	5·1863	1·273	7·3204
1·043	1·1159	·1065	1·120	3·1610	·2782	1·197	5·2124	1·274	7·3506
1·044	1·1412	·1089	1·121	3·1871	·2803	1·198	5·2381	1·275	7·3807
1·045	1·1665	·1113	1·122	3·2130	·2824	1·199	5·2639	1·276	7·4109
1·046	1·1918	·1136	1·123	3·2399	·2845	1·200	5·2901	1·277	7·4409
1·047	1·2171	·1160	1·124	3·2658	·2865	1·201	5·3160	1·278	7·4708
1·048	1·2424	·1184	1·125	3·2916	·2886	1·202	5·3422	1·279	7·5007
1·049	1·2687	·1207	1·126	3·3174	·2907	1·203	5·3681	1·280	7·5307
1·050	1·2940	·1231	1·127	3·3431	·2927	1·204	5·3941	1·281	7·5600
1·051	1·3206	·1254	1·128	3·3690	·2948	1·205	5·4203	1·282	7·5891
1·052	1·3472	·1278	1·129	3·3949	·2969	1·206	5·4462	1·283	7·6180
1·053	1·3738	·1301	1·130	3·4211	·2989	1·207	5·4720	1·284	7·6469
1·054	1·4004	·1325	1·131	3·4490	·3010	1·208	5·4979	1·285	7·6758
1·055	1·4270	·1348	1·132	3·4769	·3030	1·209	5·5239	1·286	7·7048
1·056	1·4536	·1372	1·133	3·5048	·3051	1·210	5·5506	1·287	7·7331
1·057	1·4802	·1395	1·134	3·5326	·3071	1·211	5·5786	1·288	7·7620
1·058	1·5068	·1418	1·135	3·5605	·3092	1·212	5·6071	1·289	7·7910
1·059	1·5334	·1441	1·136	3·5882	·3112	1·213	5·6360	1·290	7·8201
1·060	1.5600	·1464	1·137	3·6160	·3132	1·214	5·6651	1·291	7·8482
1·061	1·5870	·1487	1·138	3·6437	·3153	1·215	5·6942	1·292	7·8763
1·062	1·6142	·1510	1·139	3·6716	·3173	1·216	5·7233	1·293	7·9042
1·063	1·6414	·1533	1·140	3·7000	·3193	1·217	5·7522	1·294	7·9821
1·064	1·6688	·1556	1·141	3·7281	·3214	1·218	5·7814	1·295	7·9600
1·065	1·6959	·1579	1·142	3·7562	·3234	1·219	5·8108	1·296	7·9879
1·066	1·7228	·1602	1·143	3·7840	·3254	1·220	5·8401	1·297	8·0158
1·067	1·7496	·1625	1·144	3·8119	·3274	1·221	5·8680	1·298	8·0448
1·068	1·7764	·1647	1·145	3·8398	·3294	1·222	5·8962	1·299	8·0719
1·069	1·8033	·1670	1·146	3·8677	·3314	1·223	5·9242	1·300	8·1001
1·070	1·8300	·1693	1·147	3·8955	·3334	1·224	5·9523		
1·071	1·8571	·1716	1·148	3·9235	·3354	1·225	5·9801		
1·072	1·8843	·1738	1·149	3·9516	·3574	1·226	6·0081		
1·073	1·9116	·1761	1·150	3·9801	·3394	1·227	6·0361		
1·074	1·9385	·1783	1·151	4·0070		1·228	6·0642		
1·075	1·9653	·1806	1·152	4·0342		1·229	6·0925		
1·076	1·9928	·1828	1·153	5·0611		1·230	6·1205		

N.B. The column in the table on p. 728, marked *extract by weight in* ·100, is Mr. Bate's; it may be compared with the preceding short table on p. 727, and also with the table of Malt Infusions in this Dictionary. See Beer; Malt; Fermentation.

If the decimal part of the number denoting the specific gravity of syrup be multiplied by 26, the product will denote very nearly the quantity of sugar per gallon in pounds at the given specific gravity.

SACK. A general name for a large bag. Its capacity varies much; it may therefore be useful to give a few examples of its capacity in different places:—

		Winchester bushels
France:	the minimum French sack is	2·012
	maximum ditto	4·256
Brussels:	the sack is	6·90.
America:	the miller's sack is	2·00.
	ordinary sack of salt	215 lbs.
England:	the sack of wool	2 weys. 13 tods. 364 lbs.
	sack of flour or corn	280 lbs., or 2 cwts. 2 qrs.
	sack of coals formerly	3 bushels.
	do. recent	2 cwts.
	sack of dry goods	3 heaped bushels. 4 strike bushels.

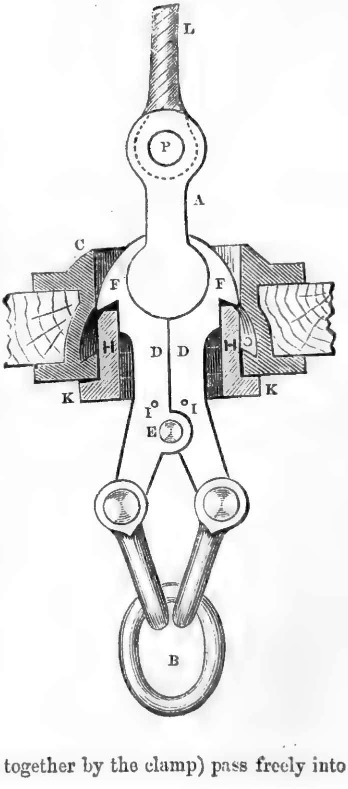
Sack is also a loose robe. A name formerly given to sherry.

SACKCLOTH. A coarse baling or wrapping.

SACKING. A coarse kind of hemp fabric, made chiefly in Dundee and in the north of Ireland.

SAFETY APPARATUS, *for the prevention of over-winding in mines.* Numerous arrangements—many of them very ingenious—have been introduced from time to time, to prevent the accidents which have very often arisen from winding the cage, containing men, over the pulley, or the load, which, breaking away, falls of course to the bottom of the shaft.

1734



Two of the latest inventions for this purpose are all that can be admitted with the space at disposal. The first of these is Walker's Detaching Hook, and the second King's Safety Apparatus.

The principle in each invention is the same, and the safety in either case is obtained from the fact, that if the load is raised above a certain point, the weight of the load compels the rope to become detached, which detaching cannot take place until the 'jaw hooks' have a firm hold on the supporting ring.

Fig. 1734 is the front view of Walker's detaching hook, with the supporting ring and clamp in section, and *fig.* 1735 is another view of the same after the hook is detached.

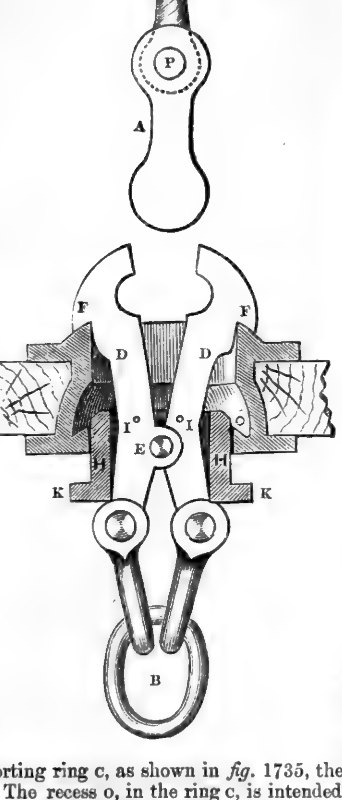
The lifting rope is attached to the shackle A, and the load to the connecting link B.

The supporting ring, C (through which the rope is constantly working), is a fixture in a baulk of timber, or iron girder, at the pit top.

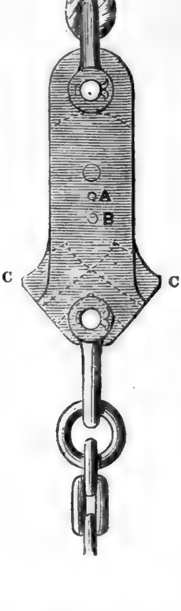
The hook consists of a pair of jaws, D, D, working on a centre-pin, E, in such a manner that the weight of the load has a tendency to open the upper limbs, which clip the strong centre-pin of the shackle A. The upper limbs are formed externally with jaw hooks, F, F. The jaws are kept together, and made to retain the shackle-pin by means of the clamp H, which is held in position by the pins I, I.

In case of overwinding, the jaw hooks (held together by the clamp) pass freely into the ring C, but the projections, K, K, of the clamp coming into contact with the bottom flange of the said ring hold the clamp stationary, while the jaws are being pulled through, the result being that the pins, I I, are sheared off, and the jaw hooks released from the restraint of the clamp. The internal diameter of the ring being the same as the width across the jaw hooks, F, F, the rope remains secure, until the jaw hooks reach the top of the ring, when, by the action of the weight of the load, they are forced open, and so hook on to the top of the supporting ring C, as shown in *fig.* 1735, the rope passing harmlessly over the pulley.

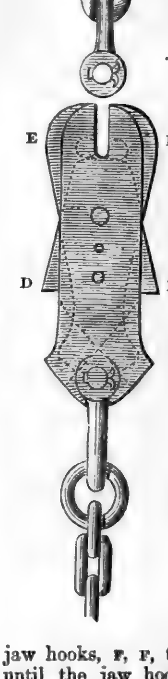
1735



1736



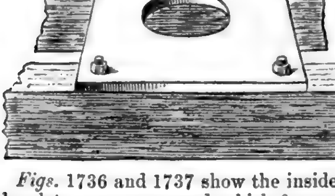
1737



The recess O, in the ring C, is intended to meet an imaginary case that experiment shows to be almost impossible, namely, that if the engine is reversed after the pins I, I, are cut, and before the hooks reach the top of the ring, the jaws will then hook into the recess, and the load remain suspended in perfect safety.

It will be observed that the upper edge of the ring C is curved to match the sweep of the jaw hooks when opening. By this arrangement all shock is avoided.

1738



King's Safety Apparatus will be perfectly understood from the accompanying figures.

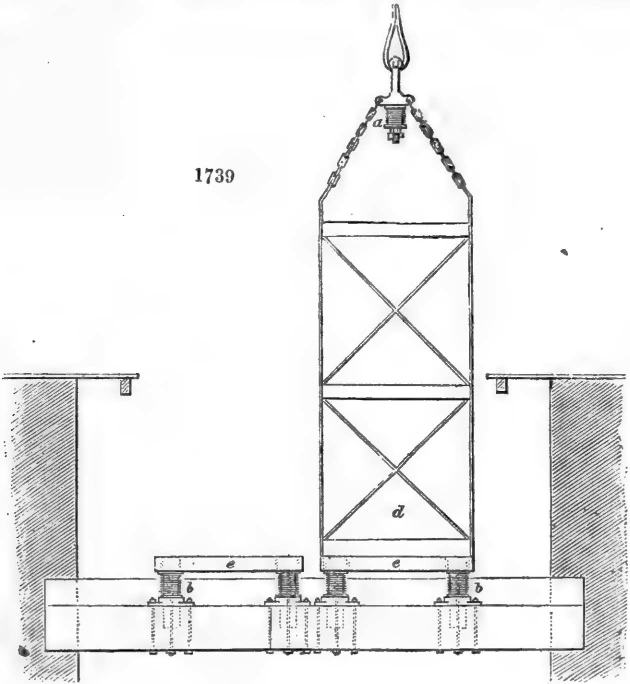
Fig. 1738 is a plan showing plate fixed on top side of beams, which must be of good strong oak, strong enough to hold three times the weight it has to carry; the two pieces of timber to be as far apart as the ring is wide; the plate to be strongly bolted with four pins.

Figs. 1736 and 1737 show the inside of plates when in work; C C, when drawn up to the plate, are compressed, which forces D D out on the opposite side, and opens the jaws of E E, which releases top shackle and leaves D D secure on the top side of plate. A is a small hole in centre of hook for a ½-inch pin to be rivetted in for holding the plates secure when in work—*care must be taken not to work without it*; when drawn up to C C it is sheared in four parts; the hole B is to put a drift in for holding the plates square, so as to punch the sheared pin out.

The detaching hook is simple in construction, and it appears to be effectual and certain in action, and is said not to be very liable to get out of order.

SAFETY CAGE. In all our collieries the men descend to their labour and are raised from the depth of the mines by winding machinery. This may be described in general terms as a stage travelling in guides fixed to the sides of the shafts. The rapidity with which these stages are moved up or down is very great, and consequently, if anything occurs to engage the attention of the man in charge of the winding-engine, the stage with its living load is either landed with injurious violence at the bottom of the pit, or it is carried over the pulley, and thus the lives of the men are sacrificed. The engraving, *fig.* 1739, shows an ingenious contrivance for obviating the blow which arises from reaching the bottom at too great a speed. *e e*, are platforms placed on india-rubber springs *b b* (see CAOUTCHOUC), on the landing at the bottom of the pit; *d*, is one of the cages which has descended, the other being supposed to be at the surface. The elasticity of these springs certainly serves to protect the men from the violence of the concussion in the event of the rope breaking, or if from any other cause they suddenly reach the bottom.

1739



Many safety cages, have been invented, in which the principles are to allow them to travel freely on their guides, so long as the rope by which they are suspended remains entire; but, in the event of its breaking, arms, levers, or catches, are released; these seize the guide-rods, and thus suddenly stop the cage. Experience has not satisfactorily confirmed the value of these arrangements.

The remarks made by the reporter on the Safety Cages exhibited in the International Exhibition of 1862 are well worthy of consideration:—

'The jury gave careful attention to all the varieties of this apparatus, and were strongly impressed with the merits of several of them, and with the desirableness of enlisting in this cause the interest of the intelligent mechanician. But they share in the repugnance of colliery viewers to trust to the action of a spring, on which most of them depend; and which, of whatever substance it is made, is sure, by degrees, to lose its elasticity, and is thus liable, unless frequently looked after, to fail at the moment when required. They are also aware that a great inconvenience, not to say danger, has been introduced by all those hitherto employed, in consequence of the apparatus being brought into play by a plunge during the rapid descent of the cage, and that hence several of those inventions, after being fairly tried for one, two, or three years, have been ultimately removed. Nor is it too much to say, although an insufficient argument if taken alone, that the employment of this apparatus has a tendency to make people careless about the examination and renewal of ropes.'

SAFETY FUSE. A woven cylinder containing gunpowder, employed in blasting rocks, especially in our mines. The safety fuse is also prepared for blasting under water. See Fuse, Safety.

SAFETY LAMP. The dangerous nature of the accumulation of fire-damp in a colliery renders it necessary that some means should be employed to produce light under such circumstances that the risks of explosion are greatly reduced.

The contrivance of a *steel mill* was formerly used, but it afforded only a gleam of light.

It consisted of a small frame of iron, mounted with a wheel and pinion, which gave rapid rotation to a disk of hard steel placed upright, to whose edge a piece of flint was applied. The use of this machine entailed on the miner the expense of an attendant, called the 'miller.' Nor was the light altogether safe, for occasionally the ignited shower of steel particles attained to a sufficient heat to inflame the fire-damp.

At length the attention of the scientific world was powerfully attracted to the means of lighting the miner with safety, by an awful catastrophe which happened at Felling Colliery, near Newcastle, on May 25, 1812. This mine was working with great vigour, under a well-regulated system of ventilation, set in action by a furnace and air-tube, placed over a rise-pit in elevated ground. The depth of winning was above 100 fathoms; 25 acres of coal had been excavated, and one pit was yielding at the rate of 1,700 tons per week. At eleven o'clock in the forenoon the night shift of miners was relieved by the day shift; 121 persons were in the mine, at their several stations, when, at half-past eleven, the gas fired, with a most awful explosion, which alarmed all the neighbouring villages. Of the 121 persons in the mine at the time of the explosion, only 32 were drawn up the pit alive, 3 of whom died a few hours after the accident. Thus no less than 92 valuable lives were instantaneously destroyed by the fire-damp.

Dr. W. Reid Clanny, of Sunderland, was the first to contrive a lamp which might burn in explosive air without communicating flame to the gas in which it was plunged. This he effected, in 1813, by means of an air-tight lamp, with a glass front, the flame of which was supported by blowing fresh air from a small pair of bellows through a stratum of water in the bottom of the lamp, while the heated air passed out through water by a recurved tube at top. By this means the air within the lamp was completely insulated from the surrounding atmosphere. This lamp was the first ever taken into a body of inflammable air in a coal-mine, at the exploding point, without setting fire to the gas around it. Dr. Clanny made another lamp upon an improved plan, by introducing into it the steam of water generated in a small vessel at the top of the lamp, heated by the flame. The objection to these lamps was their inconvenience in use.

In the course of a long and laborious investigation on the operation of the fire-damp, and the nature and communication of flame, Sir H. Davy ascertained that the explosions of inflammable gases were incapable of being passed through long narrow metallic tubes; and that this principle of security was still obtained by diminishing their length and diameter at the same time, and likewise diminishing their length and increasing their number, so that a great number of small apertures would not allow an explosion to pass, when their depth was equal to their diameter. This fact led him to trials upon sieves made of wire-gauze, or metallic plates perforated with numerous small holes; and he found that ignited gases would not pass through them.

The apertures in the gauze should never be more than $\frac{1}{20}$th of an inch square. In the working models, sent by Sir H. Davy to the mines, there were 748 apertures in the square inch, and the wire was about $\frac{1}{40}$th of an inch diameter. The cage or cylinder of wire-gauze should be made by double joinings, the gauze being folded over in such a manner as to leave no apertures. It should not be more than 2 inches in diameter, or in large cylinders the combustion of the fire-damp renders the top inconveniently hot; and a double top is always a proper precaution, fixed at a distance of about half an inch above the first top.

The principles upon which these lamps are constructed, dependent as they are upon some of the most refined researches of science, must be briefly described. Flame is gaseous matter in a state of combustion, that is, it is under the ordinary circumstances carburetted hydrogen gas in active combination with oxygen. During the intense chemical action there is a great increase of volume, carbonic acid and water-vapour escaping. Fire-damp is for the most part light carburetted hydrogen or marsh-gas.

This is formed by the changes which go on in the carbonaceous compounds of which coal is constituted, and it is condensed in the coal.

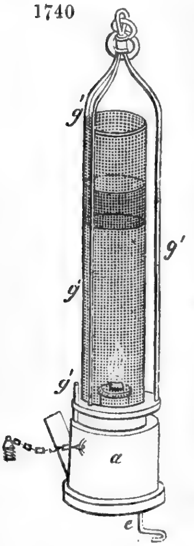
A few of the analyses which have been published by different chemists will show the composition of the fire-damp of our coal-mines.

	Carburetted hydrogen	Light air	Nitrogen	Oxygen	Carbonic acid	Name of chemist
Wallsend, Bensham seam .	77·50	...	21·10	...	1·30	Playfair.
Jarrow, Bensham seam . .	83·10	...	14·20	0·40	2·10	„
Killingworth .	66·30	23·35	6·52	...	4·03	Richardson.
Gateshead . .	94·20	...	4·50	1·30	...	Graham.

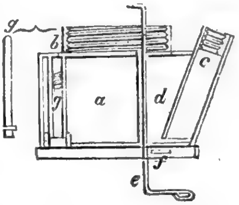
Mr. Tennant, in his 'Researches on Flame,' first noticed that burning gases would not pass through tubes of a certain diameter. Dr. Paris says, Davy was not aware of Tennant's researches. Be this as it may, he greatly extended the inquiry.

The first full account of Davy's beautiful researches was published in the 'Philosophical Transactions' for 1816, his memoir being entitled 'An account of an invention for giving light in explosive mixtures of fire-damp in coal-mines, by consuming the fire-damp.' In January 1817, the principle was announced in a paper on 'Some new experiments and observations on the combustion of gaseous mixtures, with an account of a method of preserving a continued light in mixtures of inflammable gases and air without flame.'

1740



1741



The lamp of Davy, *fig.* 1740, consists therefore of a common oil-lamp, surmounted with a covered cylinder of wire-gauze, for transmitting light to the miner without endangering the kindling of the atmosphere of fire-damp which may surround him.

The gauze-cylinder should be fastened to the lamp by a screw, *b*, *fig.* 1741, of four or five turns, and fitted to the screw by a tight ring. All joinings in the lamp should be made with hard solder; as the security depends upon the circumstance, that no aperture exists in the apparatus larger than in the wire-gauze.

The parts of the lamp are,—

1. The brass cistern *a*, *d*, *fig.* 1741, which contains the oil. It is pierced at one side of the centre with a vertical narrow tube, nearly filled with a wire which is recurved above, at the level of the burner, to trim the wick, by acting on the lower end of the wire *e* with the fingers. It is called the safety-trimmer.

2. The rim *b* is the screw neck for fixing on the gauze-cylinder, in which the wire-gauze cover is fixed, and which is fastened to the cistern by a screw fitted to *b*.

3. An aperture *c*, for supplying oil. It is fitted with a screw or a cork, and communicates with the bottom of the cistern by a tube at *f*, a central aperture for the wick.

4. The wire-gauze cylinder, *fig.* 1740, which should not have less than 625 apertures to the square inch.

5. The second top, $\frac{3}{4}$ of an inch above the first, surmounted by a brass or copper plate, to which the ring of suspension may be fixed. It is covered with a wire cap in the figure.

6. Four or six thick vertical wires, *g' g' g' g'*, joining the cistern below with the top plate, and serving as protecting pillars round the cage. *g* (*fig.* 1741) is a screw-pin to fix the cover, so that it shall not become loosened by accident or carelessness. The oil-cistern, *fig.* 1741, is drawn upon a larger scale than *fig.* 1740, to show details of the smaller parts.

When the wire-gauze safety-lamp is lighted and introduced into an atmosphere gradually mixed with fire-damp, the first effect of the fire-damp is to increase the length and size of the flame. When the inflammable gas forms so much as $\frac{1}{12}$th of the volume of the air, the cylinder becomes filled with a feeble blue flame, while the flame of the wick appears burning brightly within the blue flame. The light of the wick augments till the fire-damp increases to $\frac{1}{6}$th or $\frac{1}{5}$th, when it is lost in the flame of the fire-damp, which in this case fills the cylinder with a pretty strong light. As long as any *explosive* mixture of gas exists in contact with the lamp, so long it will give light; and when it is extinguished, which happens whenever the foul air constitutes so much as $\frac{1}{3}$rd of the volume of the atmosphere, the air is no longer proper for respiration; for although animal life will continue where flame is extinguished, yet it is always with suffering. By fixing a coil of platinum-wire above the wick, ignition may be continued in the metal when the lamp itself is extinguished; and from this ignited wire the wick may be again rekindled, on carrying it into a less inflammable atmosphere. This arrangement, however, is rarely employed.

The late Mr. John Buddle, one of the most experienced of coal-miners, wrote as follows, in the 'Journal of Science,' on the general use of the safety-lamp:—'We have frequently used the lamps where the explosive mixture was so high as to heat the wire-gauze red-hot; but on examining a lamp which has been in constant use for three months, and occasionally subjected to this degree of heat, I cannot perceive that the gauze-cylinder of iron-wire is at all impaired. I have not, however, thought it prudent, in our present state of experience, to persist in using the lamps under such circumstances, because I have observed, that in such situations the particles of coal-dust floating in the air, fire at the gas burning within the cylinder, and fly off in small luminous sparks. This appearance, I must confess, alarmed me in the first instance, but experience soon proved that it was not dangerous.

'Besides the facilities afforded by this invention to the working of coal-mines abounding in fire-damp, it has enabled the directors and superintendents to ascertain, with the utmost precision and expedition, both the presence, the quantity, and correct situation of the gas. Instead of creeping inch by inch with a candle, as is usual, along the galleries of a mine suspected to contain fire-damp, in order to ascertain its presence, we walk firmly on with the safety-lamp, and, with the utmost confidence, prove the actual state of the mine. By observing attentively the several appearances upon the flame of the lamp, in an examination of this kind, the cause of accidents which happened to the most experienced and cautious miners is completely developed; and this has hitherto been in a great measure matter of mere conjecture.'

The two first safety-lamps used in a colliery are preserved in the Museum of Practical Geology.

The action of the wire-gauze has been supposed to depend upon a cooling-process; but many experiments tried by the Editor of the present work tends to convince him that the cooling hypothesis will not explain the phenomenon. He conceives the impermeability of wire-gauze to flame to be due to a repulsive power established between the hot metal and the ignited gas, similar in character, although differing in condition, to that which prevails between water and a white-hot metal.

George Stephenson, proceeding not improbably upon the data furnished by Mr. Tennant, with that peculiar aptitude in mechanical design which ever characterised that remarkable man, at once, and without any knowledge of the researches of the chemist, devised a lamp by which air was admitted to the flame through 'apertures of wire-gauze.' This lamp is said by Mr. Brandling to have been tried in 'the Killingworth pits on Saturday, October 21, 1815.' The result, however, of a very careful examination of the question as between George Stephenson and Humphry Davy by a meeting of coal-owners, was, on October 11, 1816, a decision that the merits of discovering a real safety-lamp belonged to Davy; and on September 13, 1817, a service of plate was presented by the coal-owners at Newcastle, 'as a testimony of their gratitude for the services you have rendered to them and to humanity.'

Numerous modifications of the Davy safety-lamp have been from time to time introduced. A few of the more important must be named:—

George Stephenson modified his original plan. His modified lamp consisted of a wire-gauze cylinder about 2¼ inches diameter, and about 6 inches high, with a glass shield inside. The air for combustion was admitted through a series of perforations in the bottom, and a metal chimney, full of small holes, is fixed inside on the top of the glass-cylinder. The 'Geordie,' as the Stephenson lamp is familiarly called, has been much used in fiery collieries.

Mr. Smith, of Newcastle, improved this by covering all the perforations in the metal with wire-gauze.

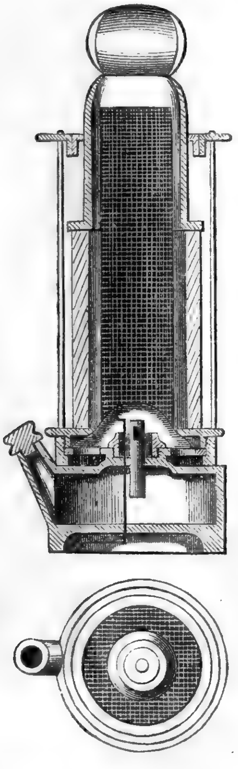
Newman, to meet the objection that strong currents of air, or of gas, could be forced through the gauze, made a lamp with a double wire-gauze, commencing from nearly the top of the flame of the lamp, leaving the lower portion with one gauze only; there was no obstruction to the light, and it has not been found possible to light a gas-flame by the Newman double gauze-lamp, whereas this may be done by suddenly driving the flame through the single gauze of the Davy.

Upton and Roberts' lamp, *fig.* 1742. This consists of a wire-gauze cylinder 5½ inches long and 1½ inch in diameter, which is attached to the cylinder in the usual manner. The lower half is protected by a thick glass-cylinder, and the remaining portion by one of copper, screwed to the upper ring of the frame. The air for combustion passes through a range of small openings in the upper part of the cistern into a space protected by a double shield of closely-compressed wire-gauze. A cone of sheet metal stands above this shield and conducts the air directly upon the wick.

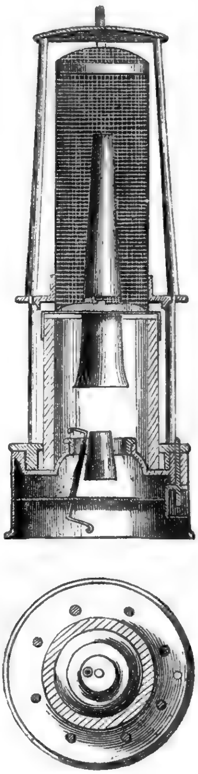
Martin's lamp was, in many respects, similar to Upton and Roberts's, but so constructed that the flame was extinguished as soon as an explosive mixture was within the glass-cylinder.

Dumesnil sought to increase the quantity of light, at the same time as he protected the flame against any rapid current. The glass shield surrounding the flame is of carefully-annealed glass, and is protected from mechanical injury by curved metal bars; a chimney of sheet metal being above the glass, and all the air being compelled to pass through apertures rendered safe by the use of wire-gauze.

1742



1743



Dr. Clanny, already named, introduced a new lamp, with an impervious metal-shield, having glass and lenses in its sides, only open at the highest part of the gauze-cylinder for about 1½ inch. Thus there is no admission of air to the lamp, or of the products of combustion from the lamp, except over the top of the shield. This in many respects resembles Mueseler's lamp, to be next described.

Mueseler's lamp is shown in section, *fig.* 1743. The cistern, opening for the wick, &c., are precisely the same as we find them in the Davy. A glass-shield occupies about two-fifths of the entire height, the lower edge resting in an annular recess on the upper surface of the cistern. A conical tube of metal carries off the products of combustion. Upon the bars which protect the glass rests the gauze-cylinder above it. When this lamp is first brought into an explosive mixture the flame is first lengthened, and then extinguished. It unfortunately happens that by turning the lamp on one side the flame is often put out, and in the mines of Liège boys are employed to relight the extinguished lamps. It is, however, stated that not less than 12,000 of these lamps are in daily use in Belgium.

Combe's and Boty's are modifications of the preceding.

Parish's lamp, one by Dr. Fyfe, and some others by Mr. Hewitson and by Mr. Biram, involve the use of mica in the place of glass.

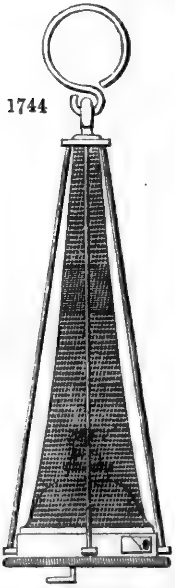
Eloin's lamp consists of a cylinder fixed upon the upper surface of the cistern and the glass-shield, which is pierced with several holes covered with wire-gauze, through which the air enters. As in Upton and Roberts's lamp, a cone assists the combustion. A copper chimney is connected with the base, pierced in the upper end with small holes, through which the products of combustion escape. The light is improved by means of a reflector, which slides upon the bars, by which the glass is protected.

Dr. Glover, Mr. Cail, and Mr. T. Y. Hall have introduced lamps which are so similar to those already named that they need not be described.

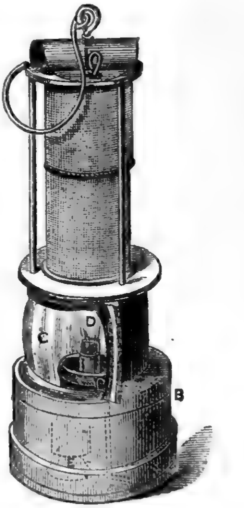
Mackworth's safety lamp was contrived by one of the Government Inspectors of Coal-mines, to meet the objections raised in resisting the general introduction of the Davy lamp into fire-damp mines. As the lamp is not used, it need not be described.

Some other lamps have been brought forward, the chief purpose being to prevent their being opened by the miner. Mr. W. P. Struve, of Swansea, constructed an ingenious safety lamp. The sketch, *fig.* 1744, will convey a better notion of it than any written description; and it is only necessary to add, that although the diameter of the gauze-cylinder at its base is considerably more than that of the Davy, yet owing to the oil-box being placed within the gauze-cylinder, instead of below it, and thus occupying a considerable portion of the internal space, the cubical contents of the cylinder do not exceed that of an ordinary Davy. The greater amount of cooling surface near the flame, and the less-obstructed admission of air thus obtained, renders it practicable and perfectly safe to use a larger wick than in the Davy, whilst the combustion of the oil is much more perfect, and the smoke very considerably diminished. The light emitted from this lamp has been carefully ascertained to be equal to that from three Davys; and, owing to the conical form of the cylinder, and the shape of the oil-box, it diffuses the light both upwards and downwards, as well as in every other direction, with less shadow than any other lamp that has been offered to the miner. From the more perfect combustion, the consumption of oil in this lamp but slightly exceeds that of the Davy, while its simplicity of construction gives great facilities for keeping it in order and for repairs. It barely weighs 1½ lb.

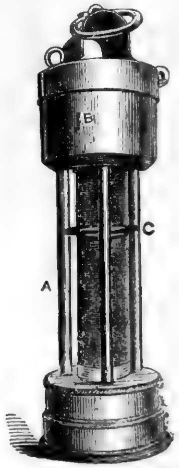
1744



1745



1746



Mr. H. D. Plimsoll has introduced a lamp which he calls the Coal-Miners' Double Safety Lamp. It is a combination of the Davy and the Clanny, having a double gauze and a glass.

Yates's Miners' safety lamp will be understood from the annexed figure (1745). B is the body of the lamp, comprising the oil-reservoir, the fixed wick-tube, and the moveable wick-holder, shown by the dotted lines at E. This is screwed on to the upper part, comprising the wire-gauze chimney, the lens C, and the metal-reflector D. The arrangements for securing this lamp are very ingenious.

Several arrangements have from time to time been introduced, to prevent the miners from opening the lamps. Mr. Bidder inserts a magnetic bar, which is turned into staples, by the use of a powerful magnet, and the lamp cannot be opened until it is again brought to the magnet, and the poles reversed.

The 'Rowe' Safety Lamp (*fig.* 1746) is a modification of the 'Relume' signal lamp, and by the same author, Mr. J. G. Rowe of Aylesbury; its object is to prevent miners opening their safety lamps while alight.

In the larger tube A (*fig.* 1746) is placed a metal bar composed of brass and steel, having a locking stud on one side. When the lamp is lighted the heat causes the bar to expand differentially, and thereby bends in the form of a bow, so that the locking stud is forced out through the screw-threads which connect the top and bottom part of the lamp.

The chamber, B, is to retain the heat, and thus prevent miners cooling the locking bar by means of a wet handkerchief, and the small ring C is inserted to stiffen the frame and keep the tube containing the locking bar quite rigid. Where glass-cylinders are used, the locking bar is placed inside them, and not in a tube.

In practice various forms are adopted, but the principle remains the same, and may shortly be described as a safety lamp locked by heat without a key; to open them the light must be extinguished, when all danger is at an end, and the metal frame allowed to get cold.

SAFETY POWDER. See EXPLOSIVE AGENTS.

SAFFLOWER. This dye-stuff has been fully described. See CARTHAMUS.

We *imported* of safflower in 1873:—

	cwts.	value
From Egypt	335	£ 3,846
British India	9,495	57,924
Other countries	246	1,575
Total	10,076	£63,345

SAFFLOWER DYEING. See CALICO-PRINTING.

SAFFRANINE. This interesting dye has been lately investigated by Hofmann and Geyger. The sample upon which they operated was obtained from the establishment of Tillman, at Crefeld. It is sometimes sold as a solid paste, and sometimes as a yellowish-red powder, containing the chloride of a colourable base in addition to carbonate of lime and chloride of calcium. The true colour is extracted by boiling the paste and filtering the solution when hot. On cooling it deposits a crystalline matter which, after repeated re-crystallisation, leaves no fixed residue. With each solution it becomes less perfectly crystalline and loses chlorine. The addition of hydrochloric acid restores the form, and is necessary to obtain normal salts. The chloride of saffranine is soluble in water and alcohol, especially when hot, but insoluble in ether and in saline solutions. The solutions are of a deep orange, and strongly fluorescent. Its composition was found to be: Carbon 68·82, hydrogen 6·09, nitrogen 15·34, chlorine 10·23. Saffranine cannot be obtained as a free base by precipitation with alkalis, as it is re-dissolved on diluting with water. It is best prepared by treating its chloride with the oxide of silver: it is thus obtained as an orange liquid, giving on concentration reddish-brown crystals. When dried at 212° they have a green metallic lustre. They dissolve in water and alcohol, but not in ether. On adding strong hydrochloric or sulphuric acid to the solutions of its salts, the red-brown colour of the liquid changes to a fine violet, which on adding more acid changes to a deep blue, then to a deep green, and lastly to a light green. Anilines of a high boiling-point are best adapted for its preparation. It may be obtained by treating them with a mixture of nitrous and arsenic acids, but the yield is small. The best results were obtained by the authors with chromic acid acting upon a liquid toluidine at 198°.

SAFFRON. (*Safran*, Fr. and Ger.) The leaves of the saffron crocus. *Hay saffron* is the only kind now found in the shops; *cake saffron* rarely containing any of that flower. *Hay saffron* consists of the stigmas with part of the style of the flowers, which have been very carefully dried. Spanish saffron is the best which is imported. It is stated that 4,320 flowers are required to produce an ounce of saffron. True cake saffron, no longer to be found, was a filamentous cake, composed of the stigmas of the flowers of the *Crocus sativus.* It is now, however, generally the leaves of the safflower (*Carthamus tinctorius*). True saffron contains a yellow matter, called *polychroïte*, because of its being susceptible of numerous changes of colour. This is obtained by evaporating the watery infusion of saffron to the consistence of an extract, digesting the extract with alcohol, and concentrating the alcoholic solution. The polychroïte remains in the form of a brilliant mass, of a scarlet red colour, transparent, and of the consistence of honey. It has no smell, with the bitter pungent taste of saffron. It is slightly soluble in water; and if it be stove-dried it deliquesces speedily in the air. According to M. Henry *père*, polychroïte consists of 80 parts of colouring-matter, combined with 20 parts of a volatile oil, which cannot be separated by distillation till the colouring-matter has been combined with an alkali. Light blanches the reddish-yellow of saffron, even when it is contained in a full phial well corked. Polychroïte, when combined with fat oils, and subjected to dry distillation, affords ammonia, which shows that nitrogen is one of its constituents. Sulphuric acid colours the solution of polychroïte indigo-blue with a lilac cast; nitric acid turns it green, of various shades, according to the state of dilution. Protochloride (muriate) of tin produces a reddish precipitate.

Saffron is employed in cookery. It is also used to colour confectionery articles, liqueurs, varnishes, and especially cakes in the west of England. It was formerly used to such an extent in Cornwall, that that one county consumed more saffron than all the rest of England.

SAGAPENUM. A gum-resin derived from an umbelliferous plant supposed to be a native of Persia. It is occasionally used instead of gum galbenum. See Dr. Pereira's 'Elements of Materia Medica.'

SAGGER. A clay case of a cylindrical shape, in which porcelain or earthenware goods are placed in the kiln to protect them from the immediate contact of the flame and smoke. See POTTERY.

SAGO (*Sagou*, Fr.; *Sago*, Ger.) is a species of starch extracted from the pith of the sago-palm, a tree which grows to the height of 30 feet in the Moluccas and the Philippines. The tree is cut down, cleft lengthways, and deprived of its pith, which being washed with water upon a sieve, the starchy matter comes out, and soon forms a deposit. This is dried to the consistence of dough, pressed through a metal sieve to corn it (which is called *pearling*), and then dried over the fire with agitation in a shallow copper pan. Sago is sometimes imported in the pulverulent state, in which it can be distinguished from arrowroot only by microscopic examination of its particles. These are uniform and spherical, not unequal and ovoïd, like those of arrowroot. In this state it is known as *sago-meal.* A factitious sago is prepared in France and Germany with potato-starch.

Of sago and sago-flower we *imported* in 1873:—

	cwts.	value
From Borneo	10,137	£ 8,892
Straits Settlements	279,766	221,798
Other countries	8,276	6,367
Total	298,179	£237,057

SAIL CLOTH. A hemp fabric, manufactured largely at Dundee.

SAINT IGNATIUS'S BEANS. The seeds of a climbing plant, native of the Philippine Islands, supposed to be a species of *Strychnos.* These beans are sometimes used instead of Nux vomica. See Dr. Pereira's 'Elements of Materia Medica.'

SAL AERATUS. A mixture of carbonate of soda and salt is so called in the United States. It is employed in making pastry and bread, mixed with a little cream of tartar or tartaric acid.

SAL-AMMONIAC. See AMMONIUM, CHLORIDE OF.

SALAMSTONE. A variety of corundum. See SAPPHIRE.

SALANGANA. See ALGÆ and SWALLOW, ESCULENT.

SALENIXON. Crude sulphate of potash obtained in the manufacture of nitric acid.

SALEP, or **SALOUP,** is the name of the dried tuberous roots of the *Orchis,* imported from Persia and Asia Minor, which are the product of a great many species of the plant, but especially of the *Orchis mascula.* Salep occurs in commerce in small oval grains, of a whitish-yellow colour, at times semi-transparent, of a horny aspect, very hard, with a faint, peculiar smell, and a taste like that of gum-tragacanth, but slightly saline. These are composed almost entirely of starchy matter, well adapted for making a thick pap with water or milk, and are hence in great repute in the

Levant, as restorers of the animal forces. Semolina is sometimes sold under this name.

SALICINE is a substance which may be obtained in white pearly crystals from the bark of the white willow (*Salix alba*), of the aspen tree (*Salix helix*), as also of some other willows. It has a very bitter taste. It has been employed for the purpose of adulterating the sulphate of quinine. Its composition is $C^{26}H^{18}O^{14}$ ($\mathbf{C^{13}H^{18}O^{7}}$), quinine being $C^{40}H^{24}N^{2}O^{4}$. The presence of nitrogen in the latter renders the salicine essentially different in its chemical as in its medicinal relations. It is said to be almost a specific against sea-sickness.

SAL MARINE is common salt (chloride of sodium). See Salt, Sea.

SAL MARTIS is protosulphate of iron.

SAL MIRABILE is sulphate of soda.

SAL PRUNELLA is fused nitre cast into cakes or balls.

SAL VOLATILE is carbonate of ammonia.

SALT, EPSOM, is sulphate of magnesia.

SALT, FUSIBLE, is phosphate of ammonia.

SALT, GLAUBER'S, is sulphate of soda.

SALT, GLAZIER'S, is sulphate of potash.

SALT, MICROCOSMIC, is the triple phosphate of soda and ammonia.

SALT OF AMBER is succinic acid.

SALT OF LEMERY is sulphate of potash.

SALT OF LEMONS is citric acid and binoxalate of potash.

SALT OF SATURN is acetate of lead.

SALT OF SODA is carbonate of soda.

SALT OF SORREL is binoxalate of potash.

SALT OF TARTAR is carbonate of potash.

SALT OF TIN is protochloride of tin.

SALT OF VITRIOL is sulphate of zinc.

SALT PERLATE is phosphate of soda.

SALTPETRE is nitre, or nitrate of potash, which see.

SALT, ROCK, SEA, or **CULINARY.** (*Chlorure de sodium; Hydrochlorate de soude*, Fr.; *Salz, Chlornatrium*, Ger.) These terms are used to designate different forms of a substance which is composed, chemically speaking, of single equivalents of sodium and chlorine, or of 39·4 parts of sodium and 60·6 of chlorine in 100 parts by weight: it is known chemically as chloride of sodium and formerly as muriate of soda.

Chloride of sodium generally occurs crystallised in the cube, and occasionally in other forms belonging to the regular system; among these varieties, the octahedron, the cubo-octahedron, and the dodecahedron, have been observed; but there is another which at first sight appears singular, and deserves notice on account of its frequent occurrence. It is called the funnel- or hopper-shaped crystal, and is a hollow, rectangular pyramid, forming on the surface of a saline solution in the course of its evaporation: it appears to commence with the formation of a small floating cube, to the edges of the upper face of which lines of other little cubes attach themselves by the edges of their lower faces. By a repetition of this proceeding, the sides of a hollow pyramid are formed, the apex of which, the single cubical crystal, is downward: the crystal sinks by degrees as the aggregation goes on above, until a pyramidal boat of considerable size is constructed.

The crystals of chloride of sodium are anhydrous, but generally contain a little water entangled in their interstices, the expansion of which causes them to decrepitate when heated. This salt is fusible at a red heat, and at a white heat volatilises. Its crystals are white, frequently perfectly transparent, of a specific gravity of 2·13, and a hardness of 2·5. A remarkable feature in this salt is, that its solubility in water increases but slightly as the temperature of the latter is raised, for, according to the experiments of M. Gay-Lussac, 100 parts of water dissolve

35·81	parts of the salt,	at a temperature of	57·0°	Fahr.
35·88	„	„	62·5°	„
37·14	„	„	140·0°	„
40·38	„	„	229·5°	„

This must be understood to apply only to the pure substance, for the presence of other salts frequently increases its solubility.

Chloride of sodium, when perfectly colourless and transparent, is perfectly diathermanous, *i.e.*, it allows the rays of heat to pass through its substance almost without perceptible interception. It stands first amongst solid bodies in this respect, all others absorbing a very considerable portion of the heat which passes through them, and some almost the whole:—

Of 100 rays of heat	Clear rock-salt transmits	92
„	Muddy ditto „ . . .	65
„	Plate glass „ . . .	24
„	Clear ice „ . . .	0

The source of heat in these experiments was red-hot platinum.

Chloride of sodium occurs in nature chiefly in two forms, either as rock-salt, forming extensive deposits, or disseminated in minute quantity through the mass of the strata which form the earth's crust. Water penetrating the layers of rock-salt, and exerting there a solvent action, gives rise to the brine springs which are found in various countries; whilst streams and rivers dissolving the same substance out of the strata through which they flow, carry it down to the sea, where it constitutes the principal saline ingredient in the waters of the ocean.

Even in mass, as rock-salt (*Sel gemme*, Fr.; *Steinsalz*, Ger.), this substance possesses a crystalline structure derived from the cube, which is its primitive form. It has generally a foliated texture, and a distinct cleavage, but it has also sometimes a fibrous structure. Its lustre is vitreous, and its streak white. It is not so brittle as nitre; its hardness =2·5, which is nearly that of alum; a little harder than gypsum, but softer than calcareous spar. Its specific gravity varies between 2·1 and 2·257. It is white, occasionally colourless, and perfectly transparent, but usually of a yellow or red, and more rarely of a blue or purple tinge. A few analyses will show the general purity of this substance.

	Wieliczka white	Vic red	Virginia, U. S.	Hall, Tyrol	Algeria	Cheshire	Marennes red	Vic grey
Chloride of sodium .	100·00	99·80	99·55	99·43	99·30	98·30	96·78	90·3
„ calcium .	..	..	trace	·25	..	..	..	..
„ magnesium .	..	..	..	·12	..	·05	·68	..
Sulphate of soda . .	..	..	..	..	..	..	..	2·0
„ lime . .	..	..	..	·20	·50	·65	1·09	5·0
„ magnesia .	..	..	..	..	..	..	·60	..
Carbonate of magnesia .	..	..	·45	..	..	..	..	..
Alumina and sesquioxide of iron . .	..	..	..	..	·20	..	..	..
Clay	..	..	..	..	..	..	·85	2·0
Water	..	·20	..	..	..	..	..	·7
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The principal impurities occurring in rock-salt are sulphate of lime, oxide of iron and clay, but the chlorides of potassium, calcium, and magnesium, the sulphates of soda and magnesia, and bituminous matters, are sometimes found in it; and occasionally shells, and insect and infusorial remains, exist enclosed in the mass. To the presence of infusoria, indeed, is attributed the red or green colour with which some varieties are tinted, which, upon analysis, are found to be absolutely pure chloride of sodium, as in the case of the second specimen quoted in the above table. Carburetted hydrogen gas in a state of strong compression is met with in some varieties, and these when dissolved in water emit a peculiar crackling sound, caused by the expansion and escape of the confined gas.

The geological position of rock-salt is very variable; it is found in all sedimentary formations, from the palæozoic to the tertiary, and is generally interstratified with gypsum, and associated with beds of clay. When the latter is present in large quantity, the term 'saliferous clay' is applied to the deposit. The great British deposits of salt in Cheshire and Worcestershire are found in the New Red Sandstone. At Northwich, in the Vale of the Weaver, the rock-salt consists of two beds, which are not less than 100 feet thick, and are supposed to constitute large insulated masses, about a mile and a half long, and nearly 1,300 yards broad. There are other deposits of rock-salt in the same valley, but of inferior importance. The uppermost bed occurs at 75 feet beneath the surface, and is covered with many layers of indurated red, blue, and brown clay, interstratified more or less with gypsum, and interspersed with argillaceous marl. The second bed of rock-salt lies at 31½ feet below the first, being separated from it by layers of indurated clay, with veins of rock-salt running between them. The lowest bed of salt was excavated to a depth of 110 feet, several years ago. Many of the German deposits of rock-salt occur in their *Bunter Sandstein*, which is the representative of part of our New Red Sandstone, and is so called because its colours vary from red to salmon and chocolate. In the Austrian Alps salt is found in oolitic limestone; at Cardonna, in Spain, in the greensand; and the famous mines of Wieliczka, in Galicia (excavated at a depth of 860 feet, in a layer 500 miles long, 20 broad, and

1,200 feet deep), it occurs in tertiary strata. But in addition to these concealed deposits, this substance presents itself in vast masses upon many parts of the earth's surface: in the high lands of Asia and Africa are often extensive wastes, the soil of which is covered and impregnated with salt, which has never been enclosed by superimposed deposits; near Lake Oroomiah, in the N.W. of Persia, it forms hills and extended plains; it abounds in the neighbourhood of the Caspian Sea, and penetrates the entire soil of the steppes of the south of Russia.

The beds of rock-salt are sometimes so thick, as at Wieliczka and Northwich, that they have not yet been sunk through, although mined for many centuries; but in ordinary cases the thickness of the layers varies from an inch or two to ten or fifteen yards. When the strata are thin, they are usually numerous, and throughout a certain extent parallel; but when explored at several points such enlargements and diminutions are observed, as to destroy this appearance of parallelism.

It has been remarked that the plants which generally grow on the sea-shore, such as the *Triglochin maritimum*, the *Salicornia*, the *Salsola Kali*, the *Aster trifolium*, or 'farewell-to-summer,' the *Glaux maritima*, &c., occur also in the neighbourhood of salt-mines and salt springs, even of those which are most deeply buried beneath the surface. It is also generally found that the interior of salt-mines is extremely dry, so that the dust produced in the workings becomes an annoyance to the miners, though in other respects the excavations are not insalubrious.

Much discussion has been raised concerning the origin of these rock-salt deposits; some asserting that they were the result of igneous agency, and others that they have been in every case deposited from solution in water. The great argument in favour of the former view appears to rest upon the fact, that chloride of sodium and hydrochloric acid gas are among the substances erupted by volcanoes; whilst, on the other hand, it is urged that the specimens of erupted chloride of sodium which have been analysed always differ much from rock-salt, since they contain a large amount of chloride of potassium; and in addition to this, the frequent occurrence of bodies such as bitumen and organic remains, and of cavities containing liquids, and in some cases gases, in almost all varieties of rock-salt, are held to furnish indisputable proof of the deposition of this substance from its aqueous solution. The occurrence of sandstone pseudomorphs in the cubical form of rock-salt, also favours this opinion; and so also does the general character of these deposits; they are usually lenticular, or irregularly-shaped beds, having a great horizontal extension, and but rarely occur in the form of dykes, or masses filling vertical fissures, which is the usual form assumed by a molten mass projected upwards from the interior of the earth. The method of its formation was, according to those who hold the aqueous theory, somewhat as follows:—A sea, such as the Mediterranean, is, by an elevation of the land at Gibraltar, cut off from communication with the ocean; the rate of evaporation from its surface is greater than the supply of water by rain and rivers, consequently the amount of salts which it holds dissolved, increases; now chloride of sodium is the principal saline constituent of sea-water, and Bischof's experiments have shown that when a solution of this salt is allowed to be at rest, the particles of salt sink, so that the lower layers soon become more saturated than the upper; concentration is then supposed to go on until at the undisturbed bottom of this inland sea a saturated solution of chloride of sodium exists, from which masses of rock-salt are slowly deposited. Its great purity is accounted for by the fact, that the other salts existing in sea-water are either far less or far more soluble than chloride of sodium; thus the carbonate and sulphate of lime would be almost wholly precipitated before the solution became sufficiently concentrated to deposit rock-salt, whilst at that degree of concentration the sulphate and chloride of magnesium would still remain for the most part in solution.

The principal European mines of rock-salt are those of Wieliczka in Galicia, excavated at a depth of 860 feet below the soil; at Hall in the Tyrol, and along the mountain range through Aussee, in Styria, Ebensee, Ischl, and Hallstadt, in Upper Austria; Hallein in Salzburg, 3,300 feet above the sea level, and Reichenthal in Bavaria; in Hungary, at Marmoros; in Transylvania and Wallachia; at Vic and Dieuze in France; at Bex, in Switzerland; in the Valley of Cardonna, and elsewhere, in Spain; and in the region around Northwich, in Cheshire, in our own country. Some of these deposits, as at Wieliczka and Northwich, are almost pure chloride of sodium; others, again, as many of the Austrian beds, are only saliferous clay; whilst others, as at Arbonne in Savoy, elevated 7,200 feet above the level of the sea, and in the region of perpetual snow, are masses of saccharoid gypsum and anhydrite, which are imbued with chloride of sodium, and which become quite light and porous when the salt has been removed by water.

Of late years valuable saline deposits have been discovered and are actively worked in the neighbourhood of Stassfurt, in Prussian Saxony, and in the adjoining duchy of Anhalt. The rock-salt which occurs at a considerable depth from the surface, is here overlain by a great thickness of mixed salts, rich in compounds of potash and magnesia. (See Abraum Salts; Potash.) It is notable that the order in which these various salts are superposed upon each other is precisely the order of their relative solubility, and hence the conclusion that the whole deposits represent the salts left by evaporation of the waters of a great salt-lake.

The natural transition from the consideration of these strata of rock-salt is to those brine springs which generally accompany them, and which have frequently first called attention to the deposits below. It has been noticed that salt springs issue, in general, from the upper portion of the saliferous strata; cases, however, occur in which the brines are not accompanied by rock-salt, and in which, therefore, their whole saline contents must be derived from the ordinary constituents of the strata. Thus, in England, besides the strong brines of the New Red Sandstone, we have salt springs issuing from the carboniferous rocks. The purest and most saturated brines are, however, found to be those which can be traced to rock-salt beds, and in the foremost rank of these stand the English springs of the Northwich, Middlewich, and Sandbach districts in Cheshire; of Droitwich and Stoke in Worcestershire; and of Weston and Shirleywich in Staffordshire; and the continental brines of Würtemberg and Prussian Saxony. The following is the composition of these saturated brines:—

Solid contents in 100 *parts of brine.*

	England				Würtemberg		Prussian Saxony
	Cheshire		Worcestershire				
	Marston	Wheelock	Droitwich	Stoke	Friedrichshall	Hall	Artern
Chloride of sodium . .	25·222	25·333	22·452	25·492	25·563	25·717	25·267
„ potassium . .	..	..	..	..	..	..	·119
Bromide of sodium . .	·011	·020	trace	trace	..	..	..
Iodide of sodium . . .	trace	trace	trace	trace	..	..	..
Chloride of magnesium .	..	·171	..	..	·005	..	·421
Sulphate of potash . .	trace	trace	trace	trace	..	..	·291
„ soda . . .	·146	..	·390	·594	..	·038	..
„ magnesia . .	..	..	..	..	·023	..	..
„ lime . . .	·391	·418	·387	·261	·437	·171	·400
Carbonate of soda . .	·036	..	·115	·016	..	..	..
„ magnesia .	·107	·107	·034	·034	..	..	..
„ manganese .	trace	trace	..	..	..	..	..
„ lime . .	..	·052	..	..	·010	·002	..
Phosphate of lime . .	trace	trace	trace	trace	..	..	..
„ sesquioxide of iron . .	trace	trace	trace	trace	..	..	..
Alumina	trace	trace	..	..	..	..	..
Silica	..	..	trace	trace	..	..	..
Solid contents . .	25·913	26·101	23·378	26·397	26·038	25·928	26·498

Compared with these may be some weaker and less pure brines, which rise from other geological formations. The brines in the United States come for the most part from Silurian sandstones, but those in the Alleghany Mountains spring from the coal; and the weak salt springs of Nauheim and Homburg, which can only be called brines because chloride of sodium is their largest constituent, rise from palæozoic strata. (See Table at top of next page.)

These weak salt springs are supposed to have no connection with beds of rock-salt, but to obtain their chloride of sodium, in common with the other salts which they contain, from the strata which they permeate. The singular brines of the Alleghany Mountains must obviously pass through strata containing little if any soluble sulphate, otherwise their chloride of barium would be separated as insoluble sulphate of baryta; and all indeed may be regarded as coming more under the head of ordinary mineral waters, which happen to contain rather a large quantity of chloride of sodium.

The next source of chloride of sodium which demands notice is found in the inland seas, salt lakes, pools, and marshes, which have their several localities obviously independent of peculiar geological formations. They appear to owe their origin to two causes, being due, first, to the formation of lakes upon, and the passage of rivers through, some of the surface deposits of salts already alluded to; and, secondly, by the cutting off of a portion of the ocean by the elevation of the land, and the consequent formation of an inland lake. To the former cause are probably due the existence of the Lake Oroomiah in the N.W. of Persia, the numerous brine pools of Southern Russia, and the Great Salt Lake of N. America. The lake Oroomiah is 82 miles

Solid contents in **100** *parts of brine.*

	America		Hesse	
	New York. Salina.	Alleghany Mountains	Nauheim	Homburg. Kaiserquelle
Chloride of sodium	13·239	3·200	2·7302	1·6000
„ potassium	...	...	...	·0027
„ barium	...	·038	...	...
„ calcium	·083	·568	...	...
„ magnesium	·046	·293	·2655	·1300
Bromide of potassium	...	trace	...	...
„ magnesium	...	...	·0097	...
Sulphate of lime	·569	...	·0047	·0018
Carbonate of lime	·014	...	·1277	·1024
„ iron	·002	...	·0015	·0096
Silicate of soda	...	...	·0006	·0031
Solid contents	13·953	4·099	3·1399	1·8496

long by 24 wide, and elevated 4,000 feet above the level of the sea; it is surrounded, especially on the east and north, by some of the most remarkable surface-deposits of rock-salt in the world, and through these salt streams are continually flowing into the lake. The Russian brine pools are situated in the salt-impregnated steppe between the rivers Ural and Wolga, and doubtless derive their saline constituents from thence. The Great Salt Lake is a saturated solution of almost pure chloride of sodium, but whence the salt is derived appears at present to be but a matter of conjecture. To the second cause the origin of the Dead Sea is frequently attributed; its surface is about 1,300 feet below that of the Mediterranean, and it is thought to have lost a column of water of that height by evaporation. The Crimean lakes also have probably originated thus.

Bischof has shown that in proportion as chloride of magnesium increases in a solution, it renders chloride of sodium and sulphate of lime more and more insoluble; he is therefore of opinion that at the bottom of the Dead Sea, and similar lakes, an impure rock-salt deposit, interstratified also with mud, is forming, similar to the saliferous clays or clayey marls which are frequently met with on the Continent.

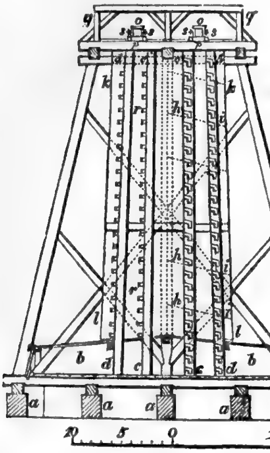
Culinary salt is prepared from each of the four sources above mentioned. It but rarely happens that rock-salt is sufficiently pure for immediate use, and when employed, as in some places on the Continent, and formerly in Cheshire, it is dissolved in water, the insoluble impurities allowed to subside, and the solution treated as a concentrated brine. From its other sources, salt is obtained by evaporation, and this is effected in two ways: 1. Entirely by the application of artificial heat; 2. By natural evaporation preceding the application of artificial heat.

The first method is employed invariably in this country, and also on the Continent when the brines contain more than 16 or 20 per cent. of chloride of sodium, the cost of fuel at different places of course regulating the application of this method. The manufacture of salt at Droitwich in Worcestershire, is said to have existed in the time of the Romans, and in Cheshire, the 'Wiches' (Nantwich, &c.) were very productive in the reign of Edward the Confessor. Some time elapsed before the method of evaporation was devised, and the original mode of obtaining the salt was by pouring the brine upon the burning branches of oak and hazel, from the ashes of which the deposited salt was afterwards collected. The process of evaporation was first conducted in small leaden vessels, which were afterwards exchanged for iron ones, having a surface of about a square yard and a depth of six inches; the size of these pans increased but slowly, for only a century since the largest pans at Northwich were but 20 feet long by 10 broad. The pans now in use in Cheshire, Worcestershire, and Staffordshire have a length of 60 or 70 feet, with a width of from 20 to 25, and a depth of about 18 inches; they are made of stout iron plates riveted together, are supported on brickwork, and have from one to three furnaces placed at one end, the flues of which are in immediate contact with the bottom of the pan. The brine is generally raised by steam-power, and its supply appears inexhaustible. The shafts are lined with wooden or iron casings to prevent the admixture of freshwater springs with the brine; the depth of the borings is in Cheshire usually from 210 to 250 feet, but at Stoke, in Worcestershire, a shaft of 225 feet was constructed, yet no satisfactory supply of brine obtained until a further boring of 348 feet was made. At Droitwich the borings are only to a depth of 175 feet, and so abundant is the supply of brine, that if the pumps cease working, it speedily rises to within nine feet of the surface, and if left unremoved soon overflows. The freedom of the brine from dilution by freshwater springs is from time to time tested by the hydrometer. From the pumps the brine is directly conveyed by means of pipes to reservoirs, from which, as the evaporation proceeds, it is admitted into the pans. As the water is vaporised, the salt is deposited and falls to the bottom of the pan; it is then drawn to the sides by the workmen, until a heap is accumulated, and from this portions are ladled out into rectangular wooden boxes with perforated bottoms, allowed to drain and solidify, removed from the boxes, and placed in the drying room; the salt of coarser grain is simply drained roughly in baskets and dried. The grain of the salt, *i.e.* its occurrence in larger or smaller crystals, is entirely the effect of temperature; the fine-grained or table salt is produced by rapid heating, and is formed at that end of the pan next the fireplace; the coarse or bay-salt is formed by the slow evaporation which goes on at the other end; whilst an intermediate variety, common salt, is produced in the middle. A pan may sometimes be slowly evaporated for the express purpose of obtaining bay-salt.

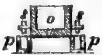
In the preparation of salt various substances have been added to the brine, with a view of improving the quality of the product: these have been chiefly bodies containing albuminous matters, which, coagulating upon the application of heat, entangle all solid impurities and carry them to the surface; blood, white-of-egg, glue, and calves' feet have thus been extensively used. There is also another class of substances employed for a different purpose. When a concentrated solution of any saline matter is evaporated, much annoyance is caused by a layer of the solid salt forming on the surface of the liquid and impeding evaporation: this is called a 'pellicle'; to obviate this, and to avoid the loss of labour entailed by constant stirring, oils, butter, or resin, have been added to the brine. The effect of the latter is said to be perfectly magical, the introduction of a very few grains being amply sufficient to clear the largest pan, and to prevent any recurrence of the 'setting over.'

When it is required to prepare salt from the weak brines which are of common occurrence in France and Germany, the second method is resorted to, and the brine is concentrated by natural evaporation previous to the application of artificial heat: this concentration was formerly effected by distributing the brine over flat inclined wooden surfaces, but it is now brought about by allowing the brine to trickle in a continuous stream through walls of thorns exposed to the sun and wind. This, which is called the method of *graduation*, is employed, among other places, at Moutiers in France, and at Nauheim, Dürrenberg, Rodenberg, and Schönebeck, in Germany. The weak brine is pumped into an immense cistern on the top of a tower, and is thence allowed to flow down the surface of bundles of thorns built up in regular walls between parallel wooden frames. At Salza, near Schönebeck, the graduation-house is 5,817 feet long, the thorn-walls are from 33 to 52 feet high, in different parts, and present a total surface of 25,000 square feet. Under the thorns, a great brine cistern, made of strong wooden planks, is placed to receive the perpetual shower of water. Upon the ridge of the graduation-house there is a long spout, perforated on each side with numerous holes, and furnished with spigots or stopcocks for distributing the brine either over the surface of the thorns or down through their mass; the latter method affording larger evaporation. The graduation-house should be built lengthwise in the direction of the prevailing wind, with its ends open. An experience of many years at Salza and Dürrenberg has shown that in the former place graduation can go on 258, and in the latter 207 days, on an average in the year; the best season being from May till August. At Dürrenberg, 3,596,561 cubic feet of water are evaporated annually. According to the weakness of the brine, it must be the more frequently pumped up, and made to flow down over the thorns in different compartments of the building, called the 1st, 2nd, and 3rd graduation. A deposit of gypsum incrusts the twigs, which requires them to be renewed at the end of a certain time. *Figs.* 1747 and 1748 represent the graduation-house of the salt-works at Dürrenberg. *a*, *a*, *a*, are low stone pillars for supporting the brine-cistern, *b*, called the *Soole-schiff*. *c*, *c*, are the inner, *d*, *d*, the outer walls of thorns; the first have perpendicular sides, the last sloping. The spars, *e*, *e*, which support the thorns, are longer than the interval between two thorn walls from *f* to *g*, *fig.* 1748, whereby they are readily fastened by their tenons and mortises. The spars are laid at a slope of 2 inches in the foot, as shown by the line *h*, *i*. The bundles of thorns are each 1½ foot thick, from 5 to 7 feet long, and are piled up in the following way:—Guide-bars are first placed in the line *k*, *l*, to define the outer surface of the thorn wall, the undermost spars *m*, *n*, are fastened upon them, and the thorns are evenly spread after the willow-withs of the bundles have been cut. Over the top of the thorn-walls are laid, through the whole length of the graduation-house, the brine-spouts *o, o*, which are secured to the upper beams; and at both sides of these spouts are the drop-spouts *p, p*, for discharging the brine by the spigots *s, s*, as shown upon a larger scale in *fig.* 1749. The drop-spouts are 6 feet long, have on each side small notches, 5 inches apart, and are each supplied by a spigot. The space above the ridge of the graduation-house is covered with boards, supported at their ends by binding-beams, *q*. *r, r*, show the tenons of the thorn-spars. Over the Soole-schiff *b*, inclined planes of boards are laid for conducting downwards the innumerable showers. The brine, which contains at first 7·692 per cent. of salt, indicates after the first shower, 11·473; after the second, 16·108; and after the third, 22. The brine thus concentrated to such a degree as to be fit for boiling, is kept in great reservoirs, of which the eight at Salza, near Schönebeck, have a capacity of 2,421,720 cubic feet, and are furnished with pipes leading to the sheet-iron salt-pans. The capacity of these is very different at different works. At Schönebeck there are 22, the smallest having a square surface of 400 feet, the largest of 1,250, and are enclosed within walls, to prevent their being affected by the cold external air. They are covered with a funnel-formed or pyramidal trunk of deals, ending in a square chimney to carry off the steam.

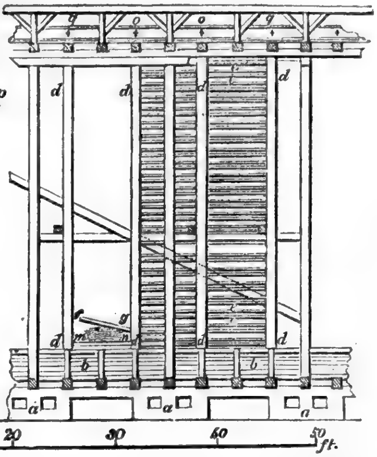
1747



1749



1748



The graduation-range should be divided lengthwise into several sections: the first, to receive the water of the spring, the lake, or the sea; the second, the water from the first shower-receiver; the third, the water from the second receiver; and so on. The pumps are usually placed in the middle of the building, and lift the brine from the several receivers below into the alternate elevated cisterns. The square wooden spouts of distribution may be conveniently furnished with a slide-board attached to each of their sides, to serve as a general valve for opening or shutting many trickling orifices at once. The rate of evaporation at Moutiers is exhibited by the following table:—

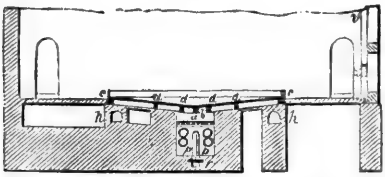
Number of showers	Total surface of the fagots	Specific gravity of the brine	Water evaporated
		1·010	...
1 and 2 . . .	5158 square feet . .	1·023	0·540
3, 4, 5, 6, 7, 8, and 9 .	2720	1·072	0·333
10	550	1·140	0·062
Total evaporation			0·935
Water remaining in the brine at the density of 1·140 .			0·065
Water assigned at the density of 1·010			1·000

From the above table it appears that no less than 10 falls of the brine have been required to bring the water from specific gravity 1·010 to 1·140, or 18° Beaumé.

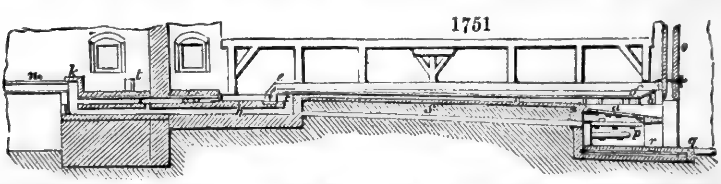
The evaporation is found to proceed at nearly the same rate with the weaker water, and with the stronger, within the above limits. When it arrives at a density of from 1·140 to 1·16, it is run off into the settling-cisterns. M. Berthier calculates, that upon an average in ordinary weather, at Moutiers, 60 kilogrammes of water (13 gallons imp.) are evaporated from the fagots, in the course of 24 hours, for every square foot of their surface. Without the aid of currents of air artificially warmed, such an amount of evaporation could not be reckoned upon in this country. In the *Schlotting*, or throwing down of the sediment, a little bullock's blood previously beaten up with some cold brine, promotes the clarification. When the brine acquires, by brisk ebullition, the density of 1·200, it should be run off from the preparation to the finishing or salting-pans. The boilers constructed at Rosenheim, in Bavaria, evaporate 3½ pounds of water for every pound of wood burnt.

Figs. 1750, 1751, 1752, represent the construction of a salt-pan, its furnace, and the salt store-room of the works at Dürrenberg: *fig.* 1752, being the ground-plan, *fig.* 1751, the longitudinal section, and *fig.* 1750, the transverse section. *a*, is the fire-grate, which slopes upwards to the back part, and is 31½ inches distant from the bottom of the pan. The ratio of the surface of the grate to that of the bottom of the pan is as 1 to 59·5; that of the air-hole into the ash-pit, as 1 to 306. The bed under the pan is laid with bricks, smoothly plastered over from *b* to *c*, in *fig.* 1750. Upon this bed the pillar *d*, *d*, &c., are built in a radiated direction, being 6 inches broad at the bottom, and tapering to 1½ inch at top. The pan is so laid that its bottom has a fall towards the middle of 2½ inches: see *e*, *f*, *fig.* 1751. The fire diffuses itself in all directions under the pan, proceeds thence through several holes, *g*, *g*, *g*, into flues, *h*, *h*, *h*, which run round three sides of the pan; the burnt air then passes through *i*, *fig.* 1752, under other pans, from which it is collected in the chimneys *k*, *k*, to be conducted into the drying-room. At *l*, *l*, there is a transverse flue, through which by means of dampers, the fire-draught may be conducted into an extra chimney, *m*. From the flues *k*, *k*, four square iron pipes, *n*, *n*, issue and conduct the burnt air into the main chimneys in the opposite wall.

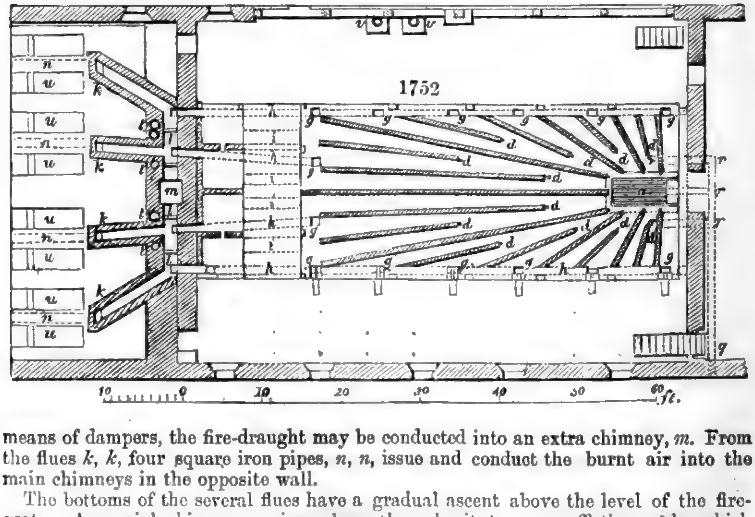
1750



1751



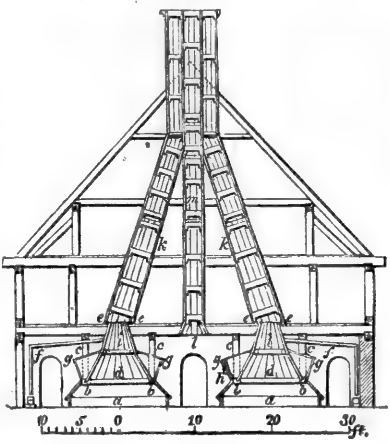
1752



The bottoms of the several flues have a gradual ascent above the level of the fire-grate. A special chimney, *o*, rises above the ash-pit, to carry off the smoke which may chance to regurgitate in certain states of the wind. *p*, *p*, are iron pipes laid upon each side of the ash-pit (see *figs.* 1750 and 1751), into which cold air is admitted by the flue *q*, *r*, where, becoming heated, it is conducted through iron pipes, *s*, and thence escapes at *t*, into the stove-room. Upon both sides of the hot flues in the stove-room, hurdle-frames, *u*, *u*, are laid, each of which contains 11 baskets, and every basket, except the undermost, holds 60 pounds of salt, spread in a layer 2 inches thick. *v*, *v*, shows the pipes by which the pan is supplied with graduated brine.

Description of the Steam-trunk in fig. 1753.—In front of the pan *a*, *a*, there are two upright posts, upon which, and in holes of the back wall, two horizontal beams, *b*, *b*, are supported. The pillars *c*, *c*, are sustained upon the bearers, *d*, *d*. At *e*, *e*, a deep quadrangular groove is made in the beams, for fixing down the four boards which form the bottom of the steam-way. In this groove any condensed water from the steam collects, and is carried off by a pipe *f*, to prevent it falling back into the pan. Upon the three sides of the pan not in contact with the wall, there are three rows of boards hinged upon planks, *b*, *b*. Behind the upper one, a board is hung on at *g*, upon which the boiled salt is laid to drain. The two other rows of boards are hooked on so as to cover the pan, as shown at *h*. Whenever the salt is sufficiently drained, the upper shelves are placed in a horizontal position; the salt is put into small baskets, and carried into the stove-room. *i*, *k*, is the steam-trunk; *l*, *m*, is a tunnel for carrying off the steam from the middle of the pan, when this is uncovered by lifting the boards.

1753



In proportion as the brine becomes concentrated by evaporation, more is added from the settling-reservoir of the graduation-house, till finally small crystals appear on the surface. No more weak brine is now added, but the charge is worked off, care being taken to remove the scum as it appears. In some places the first pan is called a schlot-pan, in which the concentration is carried only so far as to cause the deposition of the sludge, from which the same solution is run into another pan, and gently evaporated to produce the precipitation of the fine salt. This salt should be continually raked towards the cooler and more elevated sides of the pan, and then lifted out with cullender-shovels into large conical baskets, arranged in wooden frames round the border of the pan, so that the drainage may flow back into the boiling liquor. The drained salt is transferred to the hurdles or baskets in the stove-room, which ought to be kept at a temperature of from 120° to 130° Fahr. The salt is then stowed away in the warehouse.

In summer the saturated boiling brine is crystallised by passing it over vertical ropes; for which purpose 100,000 meters (110,000 yards) are mounted in an apartment 70 meters (77 yards) long. When the salt has formed a crust upon the ropes about 2½ inches thick, it is broken off, allowed to fall upon the clean floor of the apartment, and then gathered up. The salting of a charge, which would take five or six days in the pan, is completed in this way in seventeen hours, and the salt is remarkably pure, but the mother-waters are more abundant.

The mother-water contains a large quantity of chloride of magnesium, along with chloride of sodium and sulphate of magnesia. Since the last two salts mutually decompose each other at a low temperature, and are transformed into sulphate of soda, which crystallises, and chloride of magnesium, which remains dissolved, the mother-water may with this view be exposed in tanks to the frost during winter, when it affords three successive crystalline deposits, the last being nearly pure sulphate of soda.

The chloride of magnesium, or bittern, not only deteriorates the salt very much, but occasions a considerable loss of weight. It may, however, be most advantageously removed, and converted into chloride of sodium, by the following simple expedient:—Let quicklime be introduced in equivalent quantity to the chloride of magnesium present; double decomposition will take place, resulting in the precipitation of magnesia, and the formation of chloride of calcium; the latter will then react upon the sulphate of soda in the mother-water, producing sulphate of lime and chloride of sodium, the former of which, being sparingly soluble, is almost entirely separated.

In those countries, as Portugal and the coasts of the Mediterranean, where sea-water is used as the source of salt, a peculiar method of natural evaporation is resorted to, in what are called 'Salt Gardens.' Large shallow basins, the bottom of which is very smooth, and is formed of clay, are excavated along the sea-shore; they consist of:—

1st. A large reservoir, of from 2 to 6 feet in depth, communicating with the sea by means of a channel provided with a sluice. Advantage is taken of the high tide to fill this basin; and the water is allowed to remain here for some time to deposit any suspended impurities; it is then drawn off into the brine-pits.

2ndly. The brine-pits are divided into a large number of compartments by means of little banks; these all have a communication with each other, but so arranged that the water has a long circuit to make in its passage from one set to another; it frequently flows 400 or 500 yards before it reaches the extremity of this sort of labyrinth. The various divisions are distinguished by a number of technical names. They should be exposed to the north, north-east, or north-west winds.

In the month of March the water of the sea is let into these reservoirs, where a vast surface is exposed to evaporation from the first or clearing-working; the others are refilled as their contents decrease. The salt is considered to be on the point of crystallising when the water begins to grow red; soon after this, a pellicle forms on the surface, which breaks and falls to the bottom. Sometimes the salt is allowed to subside in the first compartment; but generally, the strong brine is made to pass on to the others, where a larger surface is exposed to the air; in either case, the salt as it forms is raked out, and left upon the borders to drain and dry. To get rid of the chloride of magnesium, which is one of the principal impurities of this kind of salt, it is frequently heaped up under sheds, where it is just protected from the rain, and the chloride of magnesium being a very deliquescent salt, attracts moisture from the air and drains away. The salt thus obtained partakes of the colour of the bottom on which it is formed, and is hence white, red, or grey.

The following table shows the composition of several varieties of culinary salt:—

Analyses of several varieties of Culinary Salt.

	Cheshire stoved	Lymington cat. salt	Scotch common	Königsborn, Westphalia	St. Malo, sea-salt	Moutiers	
						Des cordes	Boilers
Chloride of sodium . .	98·250	98·8	93·55	95·90	96·00	97·17	93·59
,, magnesium . .	·075	·5	2·80	...	·30	·25	·61
,, calcium . .	·025	...	...	·27	...	...	...
Sulphate of soda . . .	...	...	...	...	...	2·00	5·55
,, magnesia . .	...	·5	1·75	...	·45	·58	·25
,, lime . . .	1·550	·1	1·50	1·10	2·35	...	...
Clay and insoluble matter .	...	...	...	...	...	...	...
	99·90	99·9	99·60	97·27	99·10	100·00	100·00

The specific gravity of a saturated solution of large-grained cubical salt, is 1·1962 at 60° Fahr. 100 parts of this brine contain 25·5 of salt (100 water + 34·2 salt).

In Great Britain the rock-salt mines and principal brine-springs are in Cheshire; and the chief part of the Cheshire salt, both rock-salt and manufactured, is sent by the river Weaver to Liverpool, a very small proportion of it being conveyed elsewhere, by canal or land carriage.

There are brine-springs in Staffordshire, from which Hull is furnished with white salt, and the Worcestershire salt chiefly supplies the London market.

Within the last few years, while boring for coal in the Cleveland district near Middlesbro, Messrs. Bolchow and Vaughan discovered a considerable deposit of salt. Shafts are being sunk, not only at these works, but at the Clarence Works, belonging to Messrs. Bell Brothers. In a short time we may expect to find all the soda-works upon the Tyne suppliedwith salt from those deposits in the North Riding of Yorkshire.

According to M. Clément Desormes, engineer and chief *actionnaire* of the great salt-works of Dieuze, in France, the internal consumption of that kingdom is rather more than 200,000 tons per annum, being at the rate of 6½ kilogrammes for each individual of a population estimated at 32,000,000.

The salt produce of the United Kingdom is shown in the following returns:—

The Quantities of Cheshire Rock Salt and White Salt sent down the River Weaver in each of the last five years were:

Years	Rock-salt	White salt	Total
	tons	tons	tons
1869	58,696	901,566	960,262
1870	67,410	901,158	968,568
1871	82,765	930,551	1,013,316
1872	91,084	996,381	1,087,465
1873	95,429	918,068	1,013,497

Droitwith and Stoke Prior produced about 276,000 tons each year; and the salt-mines in Ireland about 20,000 tons annually. The total produce of the United Kingdom being a little up or down of 1,500,000 tons, and of this about 700,000 tons are annually exported.

Salt *exported* in 1874:—828,964 tons; value, 663,451*l.*

SALTS. It may be sufficient to state here that the common acceptation of a salt is that of a crystallised substance. Those formed by the union of simple bodies, as chlorine and sodium, iodine and iron, or the like; or of those formed by substances already compound, as sulphuric acid (sulphur and oxygen), with soda (sodium and oxygen), &c.; or, in the case of many of the salts formed from the organic acids exhibiting a yet more complex constitution.

Modern chemists define a salt as a body obtained from an acid by replacement of its hydrogen by a metal; thus, common salt may be derived from hydrochloric acid, or chloride of hydrogen, by replacing the hydrogen by sodium.

Salts may be either *neutral*, or such as do not exhibit any acid or alkaline properties; or *acid*, *i.e.* those in which there is an excess of acid; or *basic*, in which there is present more than one equivalent of base for each equivalent of acid.

SALT, SEDATIVE, is boracic acid.

SALT WATER, DISTILLATION OF. See WATER.

SAND (Eng. and Ger.; *Sable*, Fr.) is the name given to any mineral substance in a hard granular or pulverulent form, whether strewed upon the surface of the ground, found in strata at a certain depth, forming the beds of rivers, or the shores of the sea. The siliceous sands seem to be either original crystalline formations, like the sand of Neuilly, in 6-sided prisms, terminated by two 6-sided pyramids, or the *débris* of granitic, schistose, quartzose, or other primary crystalline rocks, and are abundantly distributed over the globe; as in the immense plains known under the names of deserts, *steppes*, *landes*, &c., which, in Africa, Asia, Europe, and America, are entirely covered with loose sterile sand. Valuable metallic ores, those of gold, platinum, tin, iron, titanium, often occur in the form of sand, or mixed with that earthy substance. Pure siliceous sands are very valuable for the manufacture of glass, for ameliorating dense clay soils, for moulding, and many other purposes.

Specimens of the finer kinds of sand, from the Isle of Wight, and the neighbourhood of Lynn, are remarkably white and beautiful. Reigate also furnishes pure siliceous sand. By far the finest samples of sand ever seen in this country were in the American department of the Great Exhibition of 1851, and did not fail to attract the notice of those interested in such matters. This sand was totally free from iron and every other source of contamination. It was as white as snow; and so far as the making of glass is concerned, no sand is equal to it: considerable quantities have been imported since that period. The principal sources of sand for the manufacture of glass are Charlton, Hastings, Derbyshire, Alum Bay, Yarmouth, Isle of Wight, Reigate, and Hartwell near Aylesbury, in England; near Llandudno, in Wales; and in Limerick, Cork, and Donegal in Ireland. These sands have all more or less of a yellow topaz hue, indicating oxide of iron, and which imparts to all glass the green tinge so very perceptible in the common window variety. To remove this oxide of iron from sand, has never yet, we believe, been attempted; though if we may judge by the trouble taken to modify its influence in the manufacture of glass, an effectual process of the kind would be a lucrative discovery. When sand containing oxide of iron is mixed with a little charcoal and subjected at a red heat to the action of chlorine gas, the whole of the iron is volatilised as chloride of iron, and the silica remains pure as soon as the excess of charcoal is burnt off: this experiment seems to suggest the possibility of purifying the glass-makers' sand, by the employment of waste muriatic acid. Even at ordinary temperatures, the solution of oxide of iron by this means might be hoped for; but there can be no practical objection to the use of a reasonable amount of heat for such a purpose, if found necessary. A beautifully white sand has been used in America in the manufacture of soap.

The sand from Alum Bay, in the Isle of Wight, is composed of—

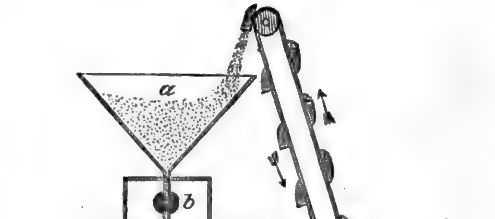
Silica	97
Alumina, with trace of oxide of iron and magnesia	2
Moisture	1
	100

The French, or Fontainebleau sand, now used in glass-making very extensively, is—

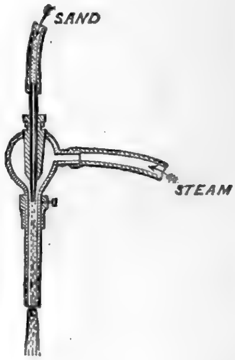
Silica	98·8
Alumina, and trace of iron	0·7
Moisture	0·5
	100

SAND-BLAST. Under the head of ENGRAVING ON GLASS, a description is given of Mr. Tilghman's process of abrading the surface of glass or stone by the action of a jet of sand driven at considerable velocity. The construction of the apparatus only will be dealt with in this place. The machine employed to direct the sand on to the object to be operated upon resembles a Gifford's injector. The arrangement will be understood by examining *fig.* 1754. *a* is the sand-box, and *b* a box containing compressed air, which passes through the tube *c*, with force proportional to the pressure exerted on the air in the box; opposite to this jet of air and sand is placed the plate of glass to be operated on. The grains of sand being drawn by suction into the air, or steam, if the latter is employed, and then projected forward with a velocity proportioned to the pressure, the sand does its work and passes off into the settling chamber *e*, from which it is again lifted by the sand-elevator to be returned into the box *a*. For cutting stone, the sand is introduced into a central iron tube, about $\frac{1}{8}$th-inch bore (*fig.* 1755), and the steam issues through an annular passage surrounding the sand-tube. A tube of chilled cast iron, 6 inches long, and $\frac{7}{16}$ths-inch bore, is fixed as a prolongation of the steam passage, and serves as a tube in which the steam mixes with the sand, and imparts velocity to the latter. The central sand-tube is connected by means of a flexible tube and funnel, with a box containing dry sand, and the outer annular tube is connected by another flexible tube with a steam-boiler.

1754



1755



SANDAL, SANTAL, or **RED SANDERS WOOD** (*Santal*, Fr.; *Sandelholz*, Ger.), is the wood of the *Pterocarpus santalinus*, a tree which grows in Ceylon and on the coast of Coromandel. The old wood is preferred by dyers. Its colouring-matter is of a resinous nature, and is therefore quite soluble in alcohol, essential oils, and alkaline lyes; but sparingly in boiling water, and hardly, if at all, in cold water. The colouring-matter which is obtained by evaporating the alcoholic infusion to dryness, has been called *santalin*. See SANTALIN.

Sandal-wood is used in India, along with one-tenth of *sapan* wood (the *Cæsalpinia sapan* of Japan, Java, Siam, Celebes, and the Philippine Isles), principally for dyeing silk and cotton. Trommsdorf dyed wool, cotton, and linen a carmine hue by dipping them alternately in an alkaline solution of the sandal-wood, and in an acidulous bath. Bancroft obtained a fast and brilliant reddish-yellow, by preparing wool with an alum-and-tartar bath, and then passing it through a boiling bath of sandal-wood and sumach.

According to Togler, wool, silk, cotton, and linen mordanted with a salt of tin, and dipped in a cold alcoholic tincture of the wood, became of a superb ponceau-red colour. With alum they took a scarlet-red; with sulphate of iron a deep violet or brown-red. Unfortunately, those dyes do not resist the influence of light.

SANDERS WOOD. See SANDAL WOOD.

SANDARACH, or *Juniper-Resin*, is a peculiar resinous substance, the product of the *Thuya articulata*, a small tree of the coniferous family, which grows in the northern parts of Africa, especially round Mount Atlas. It is imported from Mogadore.

The resin comes to us in pale yellow, transparent, brittle, small tears, of a spherical or cylindrical shape. It has a faint aromatic smell, does not soften, but breaks between the teeth, fuses readily with heat, and has a specific gravity of from 1·05 to 1·09. It contains three different resins: one soluble in spirits of wine, somewhat resembling *pinic acid* (see TURPENTINE); one not soluble in that menstruum; and a third, soluble only in alcohol of 90 per cent. It is used as pounce-powder for strewing over paper erasures, as incense, and in varnishes. The *Pterocarpus Draco* is another species of the genus: from this the Dragon's blood was formerly obtained. The wood being wounded, a resinous juice of a red colour flows out, which concretes on exposure to the air. But little of this resin is now found in commerce, the reed *Calamus Draco* producing all that is imported. Gum Kino is obtained from *Pterocarpus erinaceus*.

Sandarach is softer and less brilliant than shellac, but much lighter in colour; it is therefore used for making a pale varnish for light-coloured woods. See VARNISHES.

SANDIVER. The saline scum formed on glass-pots, known also as *Glass gall.* The name is a corruption of the French '*Saint de verre*.'

SANDSTONE. A building-stone simply formed by the cohesion of sandy particles. The most durable sandstones are such as are formed of siliceous particles cemented together by silica.

SANITARY ECONOMY. This term is used to express and to include everything which is done or can be done to the preservation of health. This includes the supply of a large quantity of pure air, the maintenance of the waters of wells and rivers in as uncontaminated a state as possible, and the removal from amongst the living of all decomposable or dead matter as speedily as possible.

SANTALIN. The chemistry of this product is by no means quite complete. Pelletier was the first who discovered and isolated santalin. Meier prepares it by treating the wood with ether; the concentrated solution yields the substance in a crystalline yet impure state. The crystals are first washed with water, and next re-dissolved in alcohol; the alcoholic solution is precipitated by acetate of lead, and the ensuing precipitate washed with boiling alcohol, and next decomposed by means of sulphuric acid in the presence of alcohol. After removing the sulphate of lead, the previously-concentrated alcoholic solution deposits santalin in the shape of small crystals of a beautiful red colour, fusing at 104°. Dr. Dussance's plan of preparing santalin is by precipitating the alcoholic extract of the wood by means of hydrated oxide of lead. After washing, the precipitate is dissolved in acetic acid, and to this solution a large quantity of cold water is added, which indeed precipitates the colouring-matter, but in a rather impure state, since the edge thus obtained does not yield good results.

Santal-wood contains on an average about 16 per cent. of santalic acid. According to Wegermann and Haeffely, the composition of santalin is $C^{30}H^{14}O^{10}$ ($\mathbf{C^{15}H^{14}O^{5}}$). Dr. Bolley considers that santal-wood contains two different colouring-matters, one of which is richer in oxygen, but poorer in hydrogen; this is the material occurring in the old dark-coloured wood. The other is found in the younger and paler variety.

According to the researches of Meier and Kimmer, santalin is accompanied by divers red and brown coloured-matters, more soluble in water than santalin itself, and the products of its oxidation. This assertion is certainly substantiated by the fact, that the young twigs of the *Pterocarpus santalinus* are internally yellow-coloured, and only become red by the action of the air.

Santalin exhibits the following properties: it is a beautiful red crystalline powder, almost insoluble in water, soluble in alcohol, ether, and acetic acid; the colouring-matter is very readily withdrawn from the acetic acid solution by albuminous substances, which retain it energetically; alkalis dissolve santalin, yielding deep violet-red solutions, from which it is thrown down unaltered by acids. Santalin fuses at 104°. (See Crookes's 'Practical Handbook of Dyeing.')

SAPAN-WOOD, or *East Indian Dye Wood*, or *Buckum-Wood*, is a species of the genus *Cæsalpinia*, to which Brazil-wood belongs. It is so called by the French, because it comes to them from Japan, which they corruptly pronounce Sapan. It is imported in pieces like the Brazil-wood, to which it is far inferior for dyeing. The decoction is used in calico-printing for red colours. In general, span wood is too unsound to be employed for turning. See Brazil-Wood.

SAP GREEN. The juice of the berries of the *Rhamus catharticus*, or common buckthorn.

SAPPHIRE. The *Sapphire, Ruby, Oriental Amethyst, Oriental Emerald*, and *Oriental Topaz*, are gems next in value and hardness to diamond; and they all consist of nearly pure alumina, with a minute proportion of iron as the colouring-matter. The following analyses show the affinity in composition of the most precious bodies with others in little relative estimation:—

	Sapphire	Corundum-stone	Emery
Alumina	98·5	89·50	86·0
Silica	0·0	5·50	3·0
Oxide of iron	1·0	1·25	4·0
Lime	0·5	0·00	0·0
	100·0	96·25	93·0

Salamstone is a variety which consists of small transparent crystals, generally six-sided prisms, of pale reddish and bluish colours. The corundum of Battagammana is frequently found in large six-sided prisms: it is commonly of a brown colour, whence it is called by the natives *Curundu gallé*, cinnamon-stone. The hair-brown and reddish-brown crystals are called adamantine spar.

Sapphire and salamstone are chiefly met with in secondary repositories, as in the sand of rivers, &c., accompanied by crystals and grains of magnetic iron ore and of several species of gems.

The finest varieties of sapphire come from Pegu, where they occur in the Capelan mountains near Syrian. Some have been found also at Hohenstein in Saxony, Bilin in Bohemia, Puy in France, and in several other countries. The red variety, the ruby, is most highly valued. Its colour is between a bright scarlet and crimson. A perfect ruby above 3½ carats is more valuable than a diamond of the same weight. If it weigh 1 carat, it is worth 10 guineas; 2 carats, 40 guineas; 3 carats, 150 guineas; 6 carats, above 1,000 guineas. A deep-coloured ruby, exceeding 20 carats in weight, is generally called a carbuncle; of which 108 were said to be in the throne of the Great Mogul, weighing from 100 to 200 carats each; but this statement is probably incorrect. The largest oriental ruby known to be in the world was brought from China to Prince Gargarin, governor of Siberia. It came afterwards into the possession of Prince Menzikoff, and constitutes now a jewel in the imperial crown of Russia. See Ruby.

A good blue sapphire of 10 carats is valued at 50 guineas. If it weighs 20 carats, its value is 200 guineas; but under 10 carats, the price may be estimated by multiplying the square of its weight in carats into half a guinea; thus, one of four carats would be worth $4^2 \times \frac{1}{2}$G. = 8 guineas. It has been said that the blue sapphire is superior in hardness to the red, but this is probably a mistake arising from confounding the corundum-ruby with the spinelle-ruby. A sapphire of a barbel-blue colour, weighing 6 carats, was disposed of in Paris by public sale, for 70*l.* sterling; and another of an indigo-blue, weighing 6 carats and 3 grains, brought 60*l.*; both of which sums much exceed what the preceding rule assigns, from which we may perceive how far fancy may go in such matters. The 'sapphire' of Brazil is merely a blue tourmaline, as its specific gravity and inferior hardness show. White sapphires are sometimes so pure, that when properly cut and polished they have been passed for diamonds.

The yellow and green sapphires are much prized under the names of oriental topaz and emerald. The specimens which exhibit all these colours associated in one stone are highly valued, as they prove the mineralogical identity of these varieties.

Besides these shades of colour, sapphires often emit a beautiful play of colours, or *chatoiement,* when held in different positions relative to the eye or incident light; and some likewise present star-like radiations, whence they are called star-stones or *asterias;* sending forth 6 or even 12 rays, that change their place with the position of the stone. This property, so remarkable in certain blue sapphires, is not however peculiar to these gems. It seems to belong to transparent minerals which belong to the rhombohedral system, and arises from the combination of certain conditions in their cutting and structure. Lapidaries often expose the light-blue variety of sapphire to the action of fire, in order to render it white and more brilliant; but with regard to those found at Expailly in France, fire deepens their colour.

SARD. A variety of chalcedony of a dark reddish-brown colour, almost approaching to black by reflected light, and very deep red, inclining to blood-red, by transmitted light. It is found under the same conditions as carnelian, but is rarer and more highly esteemed, and therefore fetches a higher price. The name is derived either from *sarx* (Gr. σάρξ, 'flesh'), in allusion to its colour, or from Sardis in Lydia, whence it is said to have been first brought. It should be remarked, however, that the sard presents, in its interior and in the middle of its ground, concentric zones, or small nebulosities, which are not to be seen in the red carnelian, properly so called. The ancients certainly knew our sard, since they have left us a great many of them engraved, but they seem to have associated under the title *Sarda* both the *sardoine* of the French and our carnelians and chalcedonies. Pliny says that the sarda came from the neighbourhood of a city of that name in Lydia, and from the environs of Babylon. Among the engraved sards which exist in the collection of antiques in the Bibliothèque Royale of Paris, there is an Apollo remarkable for its fine colour and great size. When the stone forms a part of the agate-onyx, it is called sardonyx.

SARDINE (*Atherina;* Gr. ἀθήρ, 'a spine'). A genus of fishes, belonging to the order *Acanthopterygii.* They form a very extensive fishery in the Mediterraenan. They are salted and preserved in oil, and are sent in large quantities to this country. Recently (1874) an establishment has been founded at Mevagissey in Cornwall for preserving the small pilchards in the same way as the sardines of the Mediterranean are prepared. It is thought by some that the sardine and the young pilchard are identical, but the sardine is of the genus *Atherina,* whereas the pilchard belongs to the *Clupeidæ.*

SARDONYX. A variety of onyx, composed of alternate layers of sard and white chalcedony. It much resembles agate, but the colours, usually a light clear brown and an opaque white, are arranged in flat horizontal planes. Amidst the chalcedonic series are various stones having the same general character, of mixtures of true quartz, with opal disseminated.—H. W. B.

SATIN (Eng., Fr. and Ger.) is the name of a silk stuff, first imported from China, which is distinguishable by its very smooth, polished, and glossy surface. It is woven upon a loom with at least five-leaved healds or heddles, and as many corresponding treddles. These are so mounted as to rise and fall four at a time, raising and depressing alternately four yarns of the warp, across the whole of which the weft is thrown by the shuttle, so as to produce a uniform smooth texture, instead of the chequered work resulting from intermediate decussations, as in common webs. Satins are woven with the glossy or right side undermost, because the four-fifths of the warp, which are always left there during the action of the healds, serve to support the shuttle in its race. Were they woven in the reverse way, the scanty fifth part of the warp-threads could either not support, or would be too much worn by the shuttle. See Textile Fabrics.

SATINET. A mixed fabric, woven to imitate satin.

SATIN SPAR. A fibrous variety of gypsum (sulphate of lime); when polished, used for ornamental purposes. It is sometimes a fibrous carbonate of lime.

SATIN-WOOD. A veneering wood of great beauty, the product of the *Chloroxylon Swietenia* of India. The light colour and lustrous polish of the wood, combined with the pleasing 'figure' it exhibits, renders it a favourite wood for drawing-room furniture. It is a native of Ceylon, and is found in the northern and southern —but chiefly in the eastern—districts. Above all things, it requires the most careful seasoning, for it is liable to warp and split; and once let such a misfortune happen to boards destined—say for wardrobe-panels—and the pecuniary loss is very great. Care being taken to exclude the rays of the sun, or violent alterations of heat and cold, there is little doubt of well-selected wood being seasoned successfully.

Flower satin-wood is generally obtained from the roots, and has been found of a size to yield planks 15 inches broad. Unfortunately, this is an exceptional dimension; it is not often seen in this country, for the cultivator's axe is destroying the finest satin-wood to be met with, that near the foot of the Anamallai Hills. In the Bombay Presidency it seldom reaches beyond the size of a small tree, which, when straight, would afford a log 3 by 3 inches square. The wood is very close-grained, hard, and durable, and of a light-orange colour, so light in fact, that the word 'orange' can hardly fairly be applied. Indeed, it is sometimes erroneously called 'yellow-wood,' which is another timber altogether, larger and straighter than box-wood, but not so close grained.

Satin-wood takes a fine polish, and is suited for all kinds of ornamental purposes; but it is rather apt to split. For picture-frames it is nearly equal to American maple. The timber bears submersion well, and in some instances it is beautifully feathered, and the flowered or feathered satin-wood, when first polished is one of the most beautiful woods.

SATURATION is the term employed to express the condition of a body which has taken its full dose or chemical proportion of any other substance with which it can combine; as water with a salt, or an acid with an alkali.

SATURN, EXTRACT OF. The old name of the acetate of lead.

SAW. Saws are formed from plates of sheet-steel, and are toothed, not by hand, but by means of a press and tools. Circular saws have the advantage of being divided in their teeth very accurately by means of a division-plate; this prevents irregularity of size, and imparts smoothness and uniformity of action. The larger sizes of circular saws are made in segments and connected together by means of dove-tails. All saws are hardened and tempered in oil; their irregularities are removed by nammering on blocks, and they are equalised by grinding. The several forms of teeth do not, as the casual observer may imagine, depend upon taste, but are those best fitted for cutting through the particular section, quality, or hardness of the material to be cut. The 'set' of the saw consists in inclining the teeth at the particular angle known to be the best to facilitate the exit of the saw-dust, and thereby allow the saw to operate more freely. Iron bars, shaftings, &c., are cut to length by a steel circular saw, in its soft state, the iron to be cut being presented to the saw red-hot; the saw rotates at a prodigious rate, and is kept in cutting condition, or cool, by its lower edge being immersed in water.

SAXIFRAGINE. See Explosive Agents.

SAXON BLUE. A solution of indigo in oil of vitriol. See Blue Pigments.

SCAGLIA. The red limestone of the Alps. See Limestone.

SCAGLIOLA is merely ornamental plaster-work, produced by applying a pap made of finely-ground calcined gypsum, mixed with a weak solution of Flanders glue, upon any figure formed of laths nailed together, or occasionally upon brickwork, and bestudding its surface, while soft, with splinters (*scagliole*) of spar, marble, granite, bits of concrete-coloured gypsum, or veins of clay, in a semi-fluid state. The substances employed to colour the spots and patches are the several ochres, boles, *terra di Sienna*, chrome-yellow, &c. The surface, if it be that of a column, is turned smooth upon a lathe, polished with stones of different fineness, and finished with some plaster-pap, to give it lustre. Pilasters and other flat surfaces are smoothed by a carpenter's plane, with the chisel finely serrated, and afterwards polished with plaster by friction. The glue is the cause of the gloss, but makes the surface apt to be injured by moisture, or even damp air. See Stone, Artificial.

SCARLET DYE. (*Teinture en écarlate*, Fr.; *Scharlachfärberei*, Ger.) Scarlet is usually given at two successive operations. The boilers (see Dyeing) are made of block tin, but their bottoms are formed occasionally of copper.

1. *The bouillon- or the colouring-bath.*—For 100 pounds of cloth, put into the water, when it is little more than lukewarm, 6 pounds of argal, and stir it well. When the water becomes too hot for the hand, throw into it with agitation, 1 pound of cochineal in fine powder. An instant afterwards, pour in 5 pounds of the clear mordant (see Mordant), stir the whole thoroughly as soon as the bath begins to boil, introduce the cloth, and wince it briskly for two or three rotations, and then more slowly. At the end of a two-hours' boil, the cloth is to be taken out, allowed to become perfectly cool, and well washed at the river, or winced in a current of pure water.

2. *The rougie, or finishing dye.*—The bouillon-bath is emptied and replaced with water for the *rougie*. When it is on the point of boiling, 5½ pounds of cochineal in fine powder are to be thrown in, and mixed with care; when the crust, which forms upon the surface, opens of itself in several places, 14 pounds of solution of tin (muriate of tin) are to be added. Should the liquor be likely to boil over the edges of

the kettle, a little cold water is to be added. When the bath has become uniform, the cloth is to be put in, taking care to wince it briskly for two or three turns; then to boil it bodily for an hour, thrusting it under the liquor with a rod whenever it rises to the surface. It is lastly taken out, aired, washed at the river, and dried.

Below will be found the tables of the composition of the *bouillon* and the *rougie*.

M. Lenormand stated that he had made experiments of verification upon all the formulæ of the following tables, and declared his conviction that the finest tint might be obtained by taking the *bouillon* of Scheffer and the *rougie* No. 4 of Poërner.

Tables of the Composition of the Bouillon and Rougie for 100 *pounds of Cloth or Wool.*

Composition of the Bouillon.

Names of the authors	Starch		Cream of tartar		Cochineal		Solution of tin		Common salt	
	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
Berthollet . . .	0	0	6	0	8	0	5	0	0	0
Hellot . . .	0	0	12	8	18	6	12	8	0	0
Scheffer . . .	9	0	9	6	12	4	9	6	0	0
Poërner . . .	0	0	10	15	0	0	10	15	0	0

Composition of the Rougie.

Names of the authors	Starch		Cream of tartar		Cochineal		Solution of tin		Common salt	
	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
Berthollet . . .	0	0	0	0	5	8	14	0	0	0
Hellot . . .	3	2	0	0	7	4	12	8	0	0
Scheffer . . .	3	2	3	2	5	7½	4	11	0	0
Poërner . . .	0	0	1	8	6	4	6	4	0	0
	0	0	0	0	6	4	12	8	0	0
	0	0	1	8	6	4	6	4	12	8

M. Robiquet has given the following prescription for making a *printing scarlet*, for well-whitened woollen cloth:—Boil a pound of pulverised cochineal in 4 pints of water down to 2 pints, and pass the decoction through a sieve. Repeat the boiling three times upon the residuum, mix the 8 pints of decoction, thicken them properly with 2 pounds of starch, and boil into a paste. Let it cool down to 104° Fahr., then add 4 ounces of the solution of tin and 2 ounces of ordinary muriate of tin. When a ponceau red is wanted, 2 ounces of pounded tumeric should be added.

A solution of chlorate of potash is said to beautify scarlet cloth in a remarkable manner. For several fine scarlet dyes, see 'Practical Handbook of Dyeing,' by Wm. Crookes, F.R.S. See LAC DYE; ANILINE; MUREXIDE.

SCHEELE'S GREEN is a pulverulent arsenite of copper, which may be prepared as follows:—Form, first, an arsenite of potash, by adding gradually 11 ounces of arsenious acid to 2 pounds of carbonate of potash, dissolved in 10 pounds of boiling water; next, dissolve 2 pounds of crystallised sulphate of copper in 30 pounds of water; filter each solution, then pour the first progressively into the second, as long as it produces a rich grass-green precipitate. This being thrown upon a filter-cloth, and edulcorated with warm water, will afford 1 pound 6 ounces of this beautiful pigment. It consists of, oxide of copper, 28·51, and of arsenious acid, 71·46. This green is applied by an analogous double decomposition to cloth. See CALICO-PRINTING. Much discussion has arisen relative to the use of this salt in paper-hangings, it having been supposed by many persons to have produced ill effects on those exposed to the atmosphere of such rooms.

SCHMELZE. A kind of glass prepared in Bohemia, chiefly for the purpose of receiving the red colour imparted by the oxide of gold. See GLASS.

SCHWEINFURTH GREEN is a more beautiful and velvety pigment than the Scheele's green. It was discovered in 1814, by MM. Rusz and Sattler, at Schweinfurth, and remained for many years a profitable secret in their hands. M. Liebig having made its composition known in 1822, it has since been prepared in a great many colour-works. Braconnot published, about the same time, another process for manufacturing the same pigment. Its preparation is very simple, but its formation is accompanied with some interesting circumstances. On mixing equal parts of acetate of copper and arsenious acid, each in a boiling concentrated solution, a bulky olive-green precipitate is immediately produced; while much acetic acid is set free. The powder thus obtained appears to be a compound of arsenious acid and oxide of copper, in a peculiar state; since when decomposed by sulphuric acid, no acetic odour is exhaled. Its colour is not changed by drying, by exposure to air, or by being heated in water. But, if it be boiled in the acidulous liquor from which it was precipitated, it soon changes its colour, as well as its state of aggregation, and forms a new deposit in the form of a dense granular beautiful green powder. As fine a colour is produced by ebullition during five or six minutes as is obtained at the end of several hours by mixing the two boiling solutions, and allowing the whole to cool together. In the latter case, the precipitate, which is slight and flocky at first, becomes denser by degrees; it next betrays green spots, which progressively increase, till the mass grows altogether of a crystalline constitution, and of a still more beautiful tint than if formed by ebullition.

When cold water is added to the mixed solutions immediately after the precipitate takes place, the development of the colour is retarded, with the effect of making it much finer. The best mode of procedure is to add to the blended solutions their own bulk of cold water, and to fill a globe up to the neck with the mixture, in order to prevent the formation on any such pellicle on the surface as might, by falling to the bottom, excite premature crystallisation. Thus the reaction continues during two or three days with the happiest effect.

SCOURING. This art is that which is employed for removing grease spots, &c., from cloths and furniture, which require skill beyond that of the laundry. It is divided into two distinct branches, viz. French and English cleaning. We will first give an outline of English cleaning.

Gentlemen's clothes, such as trowsers, coats, &c., are treated in the following manner. They are stretched on a board, and the spots of grease, &c., first taken out by rubbing the spots well with a brush and cold strong soap-liquor; they are then done all over with the same, but the grease spots are done first, because they require more rubbing, of course, than the other parts, and when all the substance is wet the spots will not be so easily distinguished. After treatment with the strong soap-liquor, the soap is worked by a weaker soap-liquor; the articles are then well washed off with warm water, and treated with ammonia (*if black*), solution of common salt, or dilute acid, according to circumstances. They are then drained, beaten out with a little size, pressed and dried.

Ladies' articles of dress, as shawls and woollen dresses.—The spots are first removed by rubbing them on the board with very strong soap-liquor; they are then put into a strong soap-liquor, and well worked about in it; then taken out and treated with a weaker soap-liquor, to work out the soap, &c.; rinsed with warm and cold water alternately; treated with solution of common salt or very weak acid, to maintain the colours. They are starched, if necessary, and ironed. Woollen dresses that are taken to pieces are calendered instead of ironing.

Silk dresses, &c., are always taken to pieces, and each piece done separately, and as quickly as possible. If there are any spots of grease, they are taken out first, as above mentioned. Each piece, after the spots are removed, is immediately placed in a strong soap-liquor, and well worked about in it, and then into a thinner soap-liquor; well washed out with cold water, and treated with solution of common salt, or very weak acid, or both, as required; each piece is then neatly folded and wrung separately, again folded smoothly and placed in dry sheets, and pressed, so as to remove all dampness from them; they are then put into a frame, a little size or sugar-and-water being used to stiffen and glaze; lastly, they are dried while on the frame by a charcoal fire.

Furniture, as curtains, &c.—These things are put into a tub, with a strong cold soap-liquor, and well punched about with a large wooden punch made on purpose; and a great deal depends upon this being properly done. They are then treated in the same manner in a weaker soap-liquor, well rinsed with water, treated with common salt or weak acid, as required, wrung out, and dried. Woollen furniture will generally require to be treated several times with the first strong soap-liquor, to remove the dirt, but for cotton furniture once will be generally sufficient.

Carpets.—These are well beaten, then laid down on the floor of the dye-house, and *well* scrubbed with strong cold soap-liquor, by means of a long-handled brush or broom; then treated with a weaker soap-liquor; well rinsed with water, by throwing pails of water over them, and still rubbing with the brush; treated with water, to which a *very small quantity* of sulphuric acid has been added, to retain the colours; rinsed again, hung up to drain, and then hung up in a warm room to dry.

A great point in this kind of cleaning is to use *strong cold soap-liquors*; and this cannot be done with ordinary soaps, as they congeal when cold, and on this account Field's soap is the principal soap which is used, because it is made from oil, and does not congeal. It is probaby made from the *olein* obtained in the manufacture of composite candles.

French cleaning is what is called *dry cleaning*. In this process the articles are put into camphine and worked about in it, drained, sheeted, and dried. The camphine dissolves the grease, &c., and does not injure the colours; but when things are very dirty, it does not clean so effectually as the English method. It is, however, the only process that can be employed in some cases, as in cleaning kid gloves.

SCREWS. The elementary idea of the form of the screw is obtained by regarding it as a continuous circular wedge; and it is readily modelled by wrapping a wedge-formed piece of paper around a cylinder; the edge of the paper then represents the line of the screw. The use of the screw is well known to all; and the system of cutting a rod of iron or steel into a screw scarcely requires any description. The manipulatory details and the tools used in their manufacture are admirably and most fully described in Holtzapffel's 'Turning and Mechanical Manipulation.'

SEA-HOLLY. *Eryngium maritimum.* The sea-holly—sea eryngo or sea hulver—is found on the sea-shores of Britain, and on the European and African shores of the Mediterranean Sea. The root was at one time much used medicinally. It is now prepared as a sweetmeat, and is especially candied at Colchester in Essex.

The *E. fœtidum* is used in Jamaica as a remedy for hysterical fits; and the *E. aquaticum*, sometimes called 'rattlesnake-weed,' from the circumstance of the North American Indians using it as an application to the bite of that serpent.

SEA-KALE. The *Crambe maritima* is a native of the English coast, and is found as far north as the Polar circle. The plant is blanched in spring, and the etiolated leaves are used as a delicate vegetable.

SEAL, THE. A marine animal, belonging to the class *Mammalia*, order *Carnivora*, and sub-order *Pinnipedia*. Although there are many species, only two genera, properly speaking, belong to this group, the seal (*Phoca*) and the walrus or morse (*Trichecus*). The seal is an amphibious creature; it sleeps, basks, and feeds its young on land, but has never been seen to take its food excepting when in the water. Its limbs are very short and covered with a skin, so as to resemble fins more than legs; the feet are webbed, and have the power of considerable expansion, and serve as excellent oars when the animal is in the water, but are of little service when on land, its terrestrial progression being effected by a sort of shuffling, jumping, or creeping motion; it uses these fin-like legs in climbing on to rocks or ice out of the water. It is an excellent swimmer, and, when in deep water, dives with remarkable rapidity, in an instant reappearing at perhaps a distance of fifty yards; this rapidity of motion gives it great power over its prey, which can seldom escape, except by swimming into shoal water. It feeds on almost any kind of fish, even shell-fish; but the salmon of the northern seas seems to be its favourite food. It is a native of the northern seas generally, and is found on the coasts of England and France, but is most plentiful around Greenland and Newfoundland. It is everything to the Greenlander; it supplies his food, light, and clothing, its flesh is his food, the liver being considered a dainty, and even by English sailors an agreeable dish; the fat (of which there is a large quantity, especially in the young about six weeks old) is consumed in his lamp; and the skin, being dressed in a peculiar way that renders it waterproof, furnishes him with almost all the other necessaries of life. When the skin is dressed without the hair, the Esquimaux and Greenlanders use it instead of planks for their boats, and as an outer covering for themselves, so that they are enabled to invert their canoes and themselves in the water without getting their bodies wet. The skin of the young is used as raiment for the women; and the skin of old animals to cover the houses; the stomach is filled with air and used as a fishing buoy; while the teeth furnish the heads of the hunting-spears. The skins of the *Stemmatopus cristatus* and the *Calocephalus hispidus* are sent in great quantities to Great Britain, where they are much used for hats, waistcoats, jackets, &c. The walrus or morse (*Trichecus Rosmarius*) has two large canine teeth or tusks in the upper jaw, which measure from 15 to 30 inches in length. Great numbers of these animals are annually destroyed for the sake of their tusks, the ivory of which is highly esteemed. These animals do not produce much fat, but the oil is of good quality; the skin is used for carriage-traces, wheel-ropes, &c.

Mr. Frank Buckland writes as follows on the seal-fishery:—

'When engaged two years ago in examining the salmon-fisheries of Scotland, I had the pleasure of meeting at Peterhead Captain David Gray, commanding officer of the screw-steamer 'Eclipse,' one of the principal vessels which sail annually from Scotland in pursuit of whales and seals. These vessels leave Dundee and Peterhead about

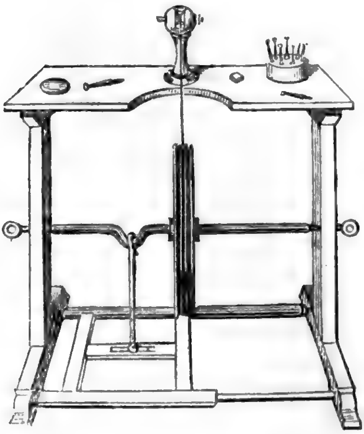
March 1; they make the ice about 72° or 73° north, in the neighbourhood of the island of Jan Mayan, a volcanic mountain rising 2,000 feet above the level of the sea. The young seals and mothers are found on the pack-ice near this island. There are four species of seals—the harp or saddle-back, the bladder-nose or hooded, the ground or bearded, and the floe or rat seal. The seals lie like flocks of sheep upon the ice, but every year they are observedly getting less and less in number.

'Captain Gray writes to me as follows in explanation of this:—

"On the seals being reached, the men are sent over the ice, the harpooners armed with rifles, the other men with seal-clubs, knife, and steel, also a rope to drag the skins to the ship. And now a work of brutal murder and cruelty goes on enough to make the hardest-hearted turn away with loathing and disgust. The harpooner chooses a place where a number of young seals are lying, knowing well that the mothers will soon make their appearance to see if the young are safe, and are then shot without mercy. This sort of work goes on for a few days, until tens of thousands of young seals are left motherless to die of starvation, not so much from the number of old ones killed (although too many of them are slain at this season, 40,000 being killed last year in March) as from those wounded and scared away. In a short time the old ones become shy and will not come near where the men are standing, but keep at a respectful distance. It is horrible to see the young ones trying to suck the carcases of their mothers, their eyes starting out of their sockets, looking the very picture of famine. They crawl over and over them until quite red with blood, poking them with their noses, no doubt wondering why they are not getting their usual food, uttering painful cries the while. The noise they make is something dreadful. If one could imagine himself surrounded by four or five hundred thousand human babies all crying at the pitch of their voices, he would have some idea of it. Their cry is very like an infant's. These motherless seals collect into lots of five or six, and crawl about the ice, their heads fast becoming the biggest part of their bodies, searching to find the nourishment they stand so much in want of. The females are very affectionate toward their young."

'The young seals are born about March 20, and are immediately slaughtered in thousands. At this time they are worth about 1*s.* per skin, and contain little or no oil. If they were not allowed to be killed before April 6, they would have time to suck and grow, and they grow very fast; this terrible "massacre of the innocents" would be prevented, the intelligent and affectionate mother-seals would be spared the agony of seeing their crying cubs slaughtered and skinned before their eyes—sometimes, as I hear, before they are quite dead—while each skin would then be worth 3*s.* or 4*s.*, and 100 seals would yield oil to the value of from 35*l.* to 40*l.* All that is required is an international agreement or treaty among the sealing-vessels, which are about 36 in number—20 from Scotland, 15 to 20 from Norway, and 2 from Germany—that an annual close-time should be given to the seals, and that they should not be killed before April 6, instead of March 20, in each year, as these seventeen days would make all the difference between their future multiplication and the present extermination which now threatens.'

1756



SEAL ENGRAVING. The art of *engraving gems* is one of extreme nicety. The stone having received its desired form from the lapidary, the engraver fixes it by cement to the end of a wooden handle, and then draws the outline of his subject with a brass needle or a diamond, upon its smooth surface.

Fig. 1756 represents the whole of the seal-engraver's lathe. It consists of a table on which is fixed the mill, a small horizontal cylinder of steel, into one of whose extremities the tool is inserted, and which is made to revolve by the usual fly-wheel, driven by a treddle. The tools that may be fitted to the mill-cylinder are the following:—*Fig.* 1757 a hollow cylinder, for describing circles, and for boring; *fig.* 1758 a knobbed tool, or rod terminated by a small ball; *fig.* 1759 a stem terminated with a cutting-disc whose edge may be either rounded, square, or sharp, being in the last case called a saw.

Having fixed the tool best adapted to his style of work in the mill, the artist applies to its cutting-point, or edge, some diamond-powder, mixed up with olive oil; and turning the wheel, he holds the stone against the tool, so as to produce the wished-for delineation and erosion. A similar apparatus is used for engraving on glass.

1757

1758

1759

In order to give the highest degree of polish to the engraving, tools of box-wood, pewter, or copper, bedaubed with moistened tripoli or rotten-stone, and lastly a brush, are fastened to the mill. These are worked like the above steel instruments. Modern engravings on precious stones have not in general the same fine polish as the ancient.

Several varieties of machine have been of late years introduced to facilitate the processes of engraving gems. Many of them involve the pentagraph, so that a seal may be engraved by the machine at once, either larger or smaller than the original from which it is copied. Most of these engraving machines are upon the principles described under CARVING BY MACHINERY.

SEAL-OIL. See OILS.

SEAL-SKIN. See FURS.

SEALING-WAX. (*Cire à cacheter*, Fr.; *Siegellack*, Ger.) The Hindoos from time immemorial have possessed the resin lac, and were long accustomed to use it for sealing manuscripts before it was known in Europe. It was first imported from the East into Venice, and then into Spain; in which country sealing-wax became the object of a considerable commerce, under the name of Spanish-wax.

If shellac be compounded into sealing-wax, immediately after it has been separated by fusion from the palest qualities of stick or seed lac, it then forms a better and less brittle article than when the shellac is fused a second time. Hence sealing-wax, rightly prepared in the East Indies, deserves a preference over what can be made in other countries, where the lac is not indigenous. Shellac can be restored in some degree, however, to a plastic and tenacious state by melting it with a very small portion of turpentine. The palest shellac is to be selected for bright-coloured sealing-wax, the dark kind being reserved for black.

The following proportions may be followed for making red sealing-wax:—Take 4 ounces of shellac, 1 ounce of Venice turpentine, and 3 ounces of vermilion. Melt the lac in a copper pan suspended over a clear charcoal fire, then pour the turpentine slowly into it, and soon afterwards add the vermilion, stirring briskly all the time of the mixture with a rod in either hand. In forming the round sticks of sealing-wax, a certain portion of the mass should be weighed while it is ductile, divided into the desired number of pieces, and then rolled out upon a warm marble slab, by means of a smooth wooden block, like that used by apothecaries for rolling a mass of pills. The oval sticks of sealing-wax are cast in moulds, with the above compound in a state of fusion. The marks of the lines of junction of the mould-box may be afterwards removed by holding the sticks over a clear fire, or passing them over a blue gas-flame. Marbled sealing-wax is made by mixing two, three, or more coloured kinds of it while they are in a semi-fluid state. From the viscidity of the several masses, their incorporation is left incomplete, so as to produce the appearance of marbling. Gold sealing-wax is made simply by stirring gold-coloured mica spangles into the melted resins. Wax may be scented by introducing a little essential oil, essence of musk, or other perfume. If 1 part of balsam of Peru be melted along with 99 parts of the sealing-wax composition, an agreeable fragrance will be exhaled in the act of sealing with it. Either lamp-black or ivory-black serves for the colouring-matter of black wax. Sealing-wax is often adulterated with rosin; in which case it runs into thin drops at the flame of a candle.

The following proportions are stated to form good sealing-wax:—

Red No. 1.—4 oz. Venetian turpentine, 6 oz. shellac, ¾ oz. colophony, 1¾ oz. cinnabar, &c.

Red No. 2.—4 oz. turpentine, 5½ oz. shellac, 1½ oz. colophony, 1¼ oz. cinnabar, magnesia to colour.

Fine Black.—4½ oz. Venetian turpentine, 9 oz. shellac, ½ oz. colophony, lamp-black mixed with oil of turpentine as much as is required.

Black.—4 oz. Venetian turpentine, 8 oz. shellac, 3 oz. colophony, lamp-black, and oil of turpentine.

Yellow.—2 oz. Venetian turpentine, 4 oz. shellac, 1¼ oz. colophony, ¾ oz. king's yellow.

Dark Brown.—4 oz. Venetian turpentine, 7½ oz. shellac, 1½ oz. brown English earth (ochre).

Light Brown.—4 oz. Venetian turpentine, 7½ oz. shellac, 1 oz. brown earth, ½ oz. cinnabar.

Dark Blue.—3 oz. Venetian turpentine, 7 oz. fine shellac, 1 oz. colophony, 1 oz. mineral blue.

Green.—2 oz. Venetian turpentine, 4 oz. shellac, 1¼ oz. colophony, ½ oz. king's yellow, ¼ oz. mountain blue.

Gold.—4 oz. Venetian turpentine, 8 oz. shellac, 14 sheets of genuine leaf-gold, ½ oz. bronze, ½ oz. magnesia with oil of turpentine.

SEA-WATER. The following has been given as the average composition of sea-water in 100 parts:—Chloride of sodium, 2·50; chloride of magnesium, 0·35; sulphate of magnesia, 0·58; carbonates of lime and of magnesia, 0·02; sulphate of lime, 0·01.

Dr. John Davy informs us that carbonate of lime is chiefly found in sea-water near the coast. Dr. George Wilson proved the existence of fluorine in the waters of the German Ocean, and Foret Lammr obtained it from sea-water collected near Copenhagen; Malaguti and Durocher have detected silver in sea-salt, and Mr. Field has shown that the copper sheathing of ships separates silver, in the process of time, from the waters of the ocean.

Lead and copper and some other metals have also been detected in sea-water, and in the ashes of some marine plants. These metals are said to exist in the sea-water in the form of chlorides, and to have been probably derived from the native sulphides of the metals by the action of the chlorine in the water.

SECRETAGE. A process in which mercury, or some of its salts, is employed to impart to the fur of animals the property of felting, which they did not previously possess. See FUR; MERCURY.

SEEDS *imported* in 1874:—

		Value
Clover and Grass . . .	256,025 cwts.	588,768*l.*
Cotton	190,549 tons	1,514,561*l.*
Flax and Linseed . . .	1,682,875 qrs.	4,678,750*l.*
Rape	289,781 „	686,719*l.*

SEGGAR. See SAGGER; POTTERY.

SELENITE. Hydrated sulphate of lime. See ALABASTER; GYPSUM.

SELENIUM, from σελήνη, *selēnē,* 'the moon,' is a chemical element, discovered by Berzelius in 1817. It occurs sparingly in combination with several metals, as lead, cobalt, copper, and quicksilver, in the Hartz, at Tilkerode; with copper and silver (*Eukairite*) in Sweden, with tellurium and bismuth in Norway, with tellurium and gold in Transylvania, in several copper and iron pyrites, and with sulphur in the volcanic products of the Lipari Islands. Selenium has been found likewise in a red sediment which forms upon the bottoms of the lead-chambers in which oil of vitriol has been made from a peculiar pyrites, or pyritous sulphur. The extraction of selenium from that deposit is a very complex process.

Selenium, after being fused and slowly cooled, appears of a bluish-grey colour, with a glistening surface; but it is a reddish-brown, and of metallic lustre when quickly cooled. It is brittle, not very hard, and has little tendency to assume the crystalline state. Selenium is dark red in powder, and transparent, with a ruby cast, in thin scales. Its specific gravity is 4·39. It softens at the temperature of 176° Fahr., is of a pasty consistency at 212°, becomes liquid at a somewhat higher heat, forming in close vessels dark yellow vapours, which condense into black drops; but in the air the fumes have a cinnabar-red colour. The atomic weight of selenium is 39·7, and its symbol Se. See Watts's 'Dictionary of Chemistry.'

SELTZER-WATER. See SODA-WATER, and WATERS, MINERAL.

SEMOULE. The name given in France to denote the large hard grains of wheat-flour retained in the bolting machine after the fine flour has been passed through its meshes. The best semoule is obtained from the wheat of the southern parts of Europe. With the semoule the fine white Parisian bread called *gruau* is baked. Skilful millers contrive to produce a great proportion of semoule from the large-grained wheat of Naples and Odessa.

Granular preparations of wheat deprived of bran are known in this country as *Semolina, Soujee,* and *Manna-croup.*

SENEGAL GUM. This gum is produced from the *Acacia Senegal,* a tree or shrub found in Arabia and the interior of Africa. See GUM.

SEPIA is a pigment prepared from a black juice secreted by certain glands of the cuttle-fish, which the animal ejects to darken the water when it is pursued. One part of it is capable of making 1,000 parts of water nearly opaque. All the species of this mollusc secrete the same juice; but the *Sepia officinalis,* the *S. loligo,* and the *S. tunicata,* are chiefly sought after for making the pigment. The first, which occurs abundantly in the Mediterranean, affords most colour; the sac containing it being extracted, the juice is to be dried as quickly as possible, because it runs rapidly into putrefaction. Though insoluble in water, it is extremely diffusible through it, and is very slowly deposited. Caustic alkalis dissolve the sepia, and turn it brown; but in proportion as the alkali becomes carbonated by exposure to air, the sepia falls to the bottom of the vessel. Chlorine blanches it slowly. It consists of carbon in an extremely-divided state, along with albumin, gelatine, and phosphate of lime.

The dried native sepia is prepared for the painter by first triturating it with a little caustic lye, then adding more lye, boiling the liquid for half an hour, filtering, next saturating the alkali with an acid, separating the precipitate, washing it with water, and finally drying it with a gentle heat. The pigment is of a brown colour, and a fine grain.

SEPTARIA (from *septum*, 'a division'), called anciently *ludus Helmontii* (the *quoits* of Van Helmont, from their form), are argillo-calcareous concretions intersected by veins of calc-spar, which, when calcined and ground to powder, form an excellent hydraulic cement.

From the regular arrangement of cracks in septaria which generally assume pentagonal forms resembling in appearance the divisions in the shell of a tortoise, they have received the common name of 'turtle-stones' or 'fossil tortoises.' The turtle-stones found in the Oxford clay at Weymouth, when cut into slabs and polished, form very handsome tables. The number of veins of calc-spar, upon which their beauty depends, renders these turtle-stones unfit for forming an hydraulic cement, in consequence of their furnishing too great a quantity of lime when calcined. Septaria fit for furnishing cement are dredged in large quantities in Chichester harbour, and off the coast of Hampshire, and are also procured from Harwich, Sheppy, and several other places. A stratum of septarian stone, forming the Broad Bench on the coast of Dorsetshire, affords an excellent cement, and is largely quarried.—H. W. B.

SERPENTINE is a mineral of the magnesian family, being a hydrated silicate of magnesia, composed of silica 43·64, magnesia 43·35, water 13·01 = 100. Its colour is either green or a mixture of red and green, seldom of a uniform tint, but generally of several shades, arranged in dotted, striped, and clouded forms. For this reason it has received the name of serpentine (or *ophiolite*, from Gr. ὄφις, *ophis*, 'a serpent,' and λίθος, *lithos*, 'stone'), from the fancied resemblance which it bears to the skin of a serpent, both in colour and in its spotted or mottled arrangement. Specific gravity, 2·5 to 2·6. It is slightly unctuous to the touch, sectile, and tough, and therefore easily cut into ornamental forms. It has been divided into *precious or noble serpentine*, comprising the purer translucent and massive varieties, with a rich olive-green colour; and *common serpentine*, or the opaque varieties, forming extensive rock masses, like those of the Lizard in Cornwall, of Anglesea, Portsoy in Banffshire, Unst and Fetlar in Shetland, and Zöblitz in Saxony.

Serpentine, though so soft as to be scratched by calcareous spar, and to be turned in the lathe, takes a good polish, and forms a very beautiful ornamental stone. At Zöblitz it has long been manufactured into a variety of articles, which find their way all over Germany; and works have been established in Cornwall, where, by means of powerful machinery, it is made into columns, vases, chimney-pieces, and other ornamental articles which have been rather extensively used. The serpentine of Portsoy is also a very beautiful stone, and was formerly exported for manufacturing into similar objects. The Cornish serpentine and steatite were at one time sent to Bristol in considerable quantities, where they were used in the manufacture of carbonate of magnesia.—H. W. B.

SESAMUM OIL, or *Teel Oil.* An oil produced from the *Sesamum orientale*, which yields the seeds known as teel seeds. It is of a peculiarly bland nature.

SEWING MACHINES. The history of these ingenious inventions has been so well told by Professor Willis, in his Report on the machinery for woven fabrics of the Paris Exhibition, that we do not hesitate to borrow from it.

At the Paris Exhibition in 1854, fourteen exhibitors came provided with sewing machines. They were of different characters, and have been divided by Mr. Willis into four classes.

Under the first class came the machines in which the needle is passed completely through the stuff, as in hand-working: 'It is so natural, in the first attempts to make an automatic imitation of handiwork, that the imitation shall be a slavish one, that we need not be surprised to find the earlier machines contrived to grasp a common needle, push it through the stuff, and pull it out on the other side.'

Thomas Stone and James Henderson, and some others, patented machines of this kind, which proved abortive. M. Heilmann exhibited an embroidering machine in 1834, in which '150, more or less, of needles are made to work simultaneously, and embroider each the same flower or device upon a piece of stuff or silk stretched in a frame and guided by a pentagraph.' Several embroidering machines have been from time to time introduced. See EMBROIDERING MACHINE.

The second class of sewing machine was that known as the chain-stitch, or 'crotchet.' This is wrought by a so-called crotchet-needle, which terminates with a hook; the needle is grasped by the opposite end, and the hook pushed through the stuff, so as to catch hold of a thread below, and, being then withdrawn, brings with it a small loop of the thread; the hook of the needle retaining this loop is then repassed through the stuff at a short distance in advance of the former passage, catches a new loop, and is again withdrawn, bringing with it the second loop, which thus passes through the first. Such a series is called chain-stitch, and may be used either to connect two pieces together, or as an embroidery stitch, for which it is well adapted by its ornamental and braid-like appearance. M. Thimonnier patented in 1830 the first machine of this character. M. Magnin was associated with Thimonnier in 1848 in a patent for improvements, and in 1851 it was exhibited in London.

In 1849 Morey and Johnson patented a sewing machine in this country, in which a needle with an eye near the point, perpendicular to the cloth, was combined with a hooked instrument parallel to the cloth, for effecting the same purpose as the crochet-needle. Mr. Singer improved on this, and he introduced a contrivance by which his machine forms a kind of knot at every eighth stitch.

The third class of sewing machines is wrought by two threads, and, as the stitch produced by them is known in America as the *mail-bag stitch*, it may be presumed it was employed by the makers of that article before the introduction of the machine. In the usual mechanical arrangement for its production, a vertical needle, having the eye very near the point, is constantly supplied with thread from a bobbin, and is carried by a bar, which is capable of an up-and-down motion. The cloth being placed below the needle, the latter descends, pierces it, and forms below it a small loop, with the thread carried down by its eye. A small shuttle, which has a horizontal motion beneath the cloth, is now caused to pass through this loop, carrying with it its own thread. The needle rises, but the loop is retained by the shuttle-thread. The cloth being next advanced through the space of a stitch, the needle descends again, and a fresh loop is made. This process being repeated along the line of the seam, it results that the upper thread sends down a loop through such needle-hole, and that the lower thread passes through all these loops, and thus secures the work. The first machine for producing this stitch was invented by Walter Hind, of New York, in 1834. Several patents for producing this stitch have been obtained. Howe's patent was one of the most practical. Mr. Thomas of London became the possessor of Howe's patent. This was improved, and a new patent obtained in June 1846, which was modified in December of that year. This machine has been extensively used. This invention, says the patentee, consists in certain novel arrangements of machinery, whereby fabrics of various textures may be sewn together in such a manner as to produce a firm and lasting seam. By this invention a shuttle, when the point of the needle has entered the cloth or other fabric under operation and formed a loop of thread, passes through that loop and leaves a thread on the face of the cloth, by which means the needle, when it is withdrawn from the cloth, instead of drawing back the thread with it, leaves a tightened loop on the opposite side of the cloth to that at which it entered. The fabric then passing forward to the distance of the length of the stitch required, is again pierced with the needle, and a stitch is in like manner produced. A figure of this machine is shown (*fig.* 1760), which will be understood from the following description:—

1. *The needle.* Place the needle in the slide A, with its flat side towards the shuttle, and the grooved side in front. Turn the wheel of the machine round till the line *g*, on the gun-metal slide, is level with the line *g* on the iron check. Place the *eye* of the needle level with the top of the shuttle-box, and screw the needle fast.

2. If the eye is above the box when the marks correspond, the needle is too high; if the eye cannot be seen, the needle is too low.

3. The needle should pass down the centre of the hole in the shuttle-box; but if it does not, it can be made to do so by bending.

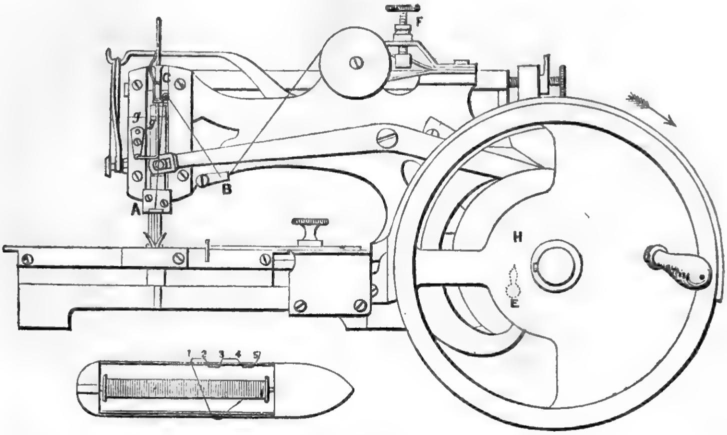
4. *The needle-thread* runs from the top of the reel, through the rings B, C, and through the eye of the needle.

5. *The shuttle.* It is necessary that the first coil of cotton be wound closely on the bobbin, or it will be difficult to make it lie side by side like that on ordinary reels. The reels should not be filled above the brass, and the cotton or silk should be free from knots, which sometimes pull the wire out of the shuttle.

6. The thread must run from the under side of the bobbin, round the wire and out through holes, Nos. 1, 2, and 3. If the thread is not tight enough, miss No. 3 and let it come out through Nos. 4 or 5, or it may be drawn through five holes. Put the shuttle in the box, turn the wheel round once, then pull the end of the needle-

thread and draw up the shuttle-thread through the hole in the plate. Place the cloth under the mover, and the machine is ready for work. The proper time for turning the work to sew a corner, &c., is when the spring at the top is lifted off.

1760



7. The length of stitch is regulated by the screw E at back of machine.

8. The tightness of the needle-thread is regulated by the screw F.

9. The tightness of the shuttle-thread is regulated by passing the thread through more or less holes.

11. The quantity of thread pulled off the reel for each stitch is regulated by the position of the piece of brass B. The lower the hole at its end, the greater the quantity pulled off: when the cloth is thick, more thread is used, and the end of the brass B should be lowered; when thin, raised. It should be in such a position that the trumpet C is drawn nearly down to the pin on the slide when the shuttle passes through the loop.

A patent was obtained by John Thomas Jones, of Glasgow, in February 1859, for a sewing machine presenting many novelties and improvements. Mr. Jones's patent well explains his machine; we therefore transfer his description to our pages.

The machine consists, under one modification, of an open frame, having a platform top upon which the sewing or stitching operations are carried on. Beneath this platform, and near one end of it, is a short transverse horizontal first-motion shaft running in bearings in the framing, and carrying a long crank, a connecting rod from which is jointed at its opposite end, directly the shuttle-driver or slide-piece, working in a horizontal guide recess beneath the opposite or front end of the platform or table. The first-motion shaft has also another and shorter crank upon it, the stud-pin of which is connected to the pin of the longer crank by an overhanging link piece, provision being made for the adjustment of the relative positions of the two cranks as regards their sequence of revolution. It is this shorter crank which actuates the needle movement, the pin being entered into a differentially slotted or operated cam piece, forming the pendent lower end of a bent lever, working on a stud-centre, in the interior of the overhead bracket or pillar arm of the framing. The centre on which this lever works is in the horizontal part of the overhead bracket arm, and its opposite or free-working end has a rectangular slot in it to embrace a rectangular block of metal working freely upon a lateral centre-stud upon the vertical needle-carrying bar. In this way the needle has imparted to it a differential reciprocatory vertical movement, the peculiar connection of the needle bar with the actuating lever having the effect of marking the needle in the most accurate manner, and preventing jarring and wear. These are the whole of the primary movements for working the stitches, which may be of various kinds, as made up from the combined action of the needle and shuttle, or thread-carrier; the form of the slotted piece or operated cam in the end of the needle lever, being variable to suit any required peculiarity of needle movement, the main elements of which are a direct up-and-down motion without a stop or rest, until at the termination of the down stroke, when a short rise takes place, succeeded by a rest to allow of the due looping and stitching of the thread. The feed of the fabric to be sewed is effected by the operation of a short vertical lever piece with a cranked and slotted lower end, where it is set on a fixed stud in the framing. This feed-lever has a roughened or toothed upper end, the teeth or asperities being set or inclined in the direction of the fabric's traverse. After each stitching action, the feed-lever being lowered just beneath the operating level, is raised up so as to press firmly against the under side of the fabric, and nip it between the stationary spring pressed above. This elevation of the roughened face is effected by the traverse of the shuttle-carrier, which at its back stroke comes against the inclined tail of a short horizontal lever set on a stud in the framing, and having its opposite bent end bearing against the lower end of the feed lever, at the part where it is carried by its slot upon the holding stud. At the commencement of the return of the shuttle, an inclined piece upon the shuttle-carrier bears against a lateral stud upon one end of a short rocking or oscillatory shaft set in bearings in the framing, the other end of the shaft having a lever arm bearing against the side of the feed-lever. In this way the feed-lever is traversed forward in its elevated position, carrying forward the fabric for the succeeding stitch. The adjustment of the spring presser is effected by an upper screw in the end of the bracket arm of the framing, the lower end of the screw bearing upon a lateral pressing piece which rests or abuts on the top end of a flattened helical spring upon the presser bar. The latter can be set up clear out of work by means of a small cam lever set on a stud in the stationary guide of the presser bar, the cam bearing against a lateral stud in the bar, so that by setting the lever up or down, the cam is correspondingly turned, and the lever set up or down, as required. The actual pressing or resisting foot of the bar is a bent piece of metal screwed on to the bar, and being thus removable to allow of various forms of feet guides, or presser surface pieces, being put on to suit varieties of forms of stitching.

This machine, or a modification of it, is available for working a duplex, or other stitching action without involving further modification of the prime movers. In working a duplex arrangement, two needles and two shuttles are used, each needle and shuttle working independently, so as to allow of sewing in two different and independent lines with one set of actuating parts. To aid the shuttle action there is attached to its side a flat curved blade spring, one end of which is free, but hooked into a hole in the body of the shuttle. Thus, as the shuttle traverses forward, the sewing thread is drawn beneath the hooked end portion of the spring, so as to be nipped against the shuttle. The thread is thus held, and the proper loop is secured at the part immediately outside the nipped portion. With this arrangement the needle can never work on the wrong side of the shuttle-thread. Provision is also made for securing an independent shuttle-thread controller. This is a nipper or retainer worked from any convenient part of the mechanism, but entirely independent of the shuttle movement. This may be arranged in various ways, the object being the variable and efficient control or retention of the thread, without interfering in any way with the fixed and determined action of the shuttle. Instead of fixing a horizontal shuttle race ,or guide track, in the framing, the shuttle-driver is itself made the race or carrier, so as to secure both offices in one detail or arrangement. A hook or finger, actuated by any convenient part of the movement, is also used for retaining the needle thread for any desired time after being passed through the fabric; this facilitates the movement or action of the needle bar. The shuttle race, when one is used, is made quite independent of the machine, so that it can be changed at any time to suit various-sized shuttles by merely slipping in or taking out the part. The portion of the framing carrying the shuttle race is cast in one piece with the main body of the platform, but the table or plate on which the stitching takes place is a loose piece slotted down the middle for the working movements, and fitted into its position by pins cast upon it, and entered into corresponding recesses in the main base.

There exists a fourth class of sewing machines, which produce more complex stitches than the preceding. These are formed by sewing two threads, which mutually interlace each other in chain-stitch, so as to avoid the unravelling to which the simple chain-stitch is subject, and also are intended to meet an objection which is urged against the shuttle-stitch machines, on the ground that, as the shuttle must be small to enable it to pass through the loop formed by the needle thread, so the bobbin carried by the shuttle can only obtain a moderate length of thread. Thus the operation is stopped at short intervals to supply fresh bobbins to the shuttle. Several patents have been obtained for compound chain-stitch machines: two in America, in 1851 and 1852, by Grover and Baker; another in 1852 by Avery; and another by M. Journaux Le Blond.

In England, as in France, all the most promising American patents have been repatented, and the use of the machine is rapidly extending itself. The sewing machine has acquired so prominent a position, and shown itself to be so useful, as to deserve the time and attention of able mechanists. It is now made in a considerable variety of forms to suit it to the various purposes to which it is now applied. We find it in almost every large manufactory; and in nearly every family, the hand-sewing machine has its place.

SHADDOCK. The fruit of the *Citrus decumana*, which is much cultivated in the West Indies. It is sold in this country as the 'Forbidden Fruit.'

SHAFT, in *mining*, signifies a perpendicular or slightly-inclined pit. See MINING.

SHAGREEN. (*Chagrin*, Fr.; *Schagrin*, Ger.) The true oriental shagreen is essentially different from all modifications of leather and parchment. It approaches the latter somewhat, indeed, in its nature, since it consists of a dried skin, not combined with any tanning or foreign matter whatever. Its distinguishing characteristic is having the grain or hair side covered over with small rough round specks or granulations.

It is prepared from the skins of horses, wild asses, and camels; of strips cut along the chine, from the neck towards the tail, apparently because this stronger and thicker portion of the skin is best adapted to the operations about to be described. These fillets are to be steeped in water till the epidermis becomes loose, and the hairs easily come away by the roots; after which they are to be stretched upon a board, and dressed with the currier's fleshing-knife. They must be kept continually moist, and extended by cords attached to their edges, with the flesh-side uppermost upon the board. Each strip now resembles a wet bladder, and is to be stretched in an open square wooden frame by means of strings tied to its edges, till it be as smooth and tense as a drum-head. For this purpose it must be moistened and extended from time to time in the frame.

The grain or hair-side of the moist strip of skin must next be sprinkled over with a kind of seed called *Allabuta*, which are to be forced into its surface either by tramping with the feet, or with a simple press, a piece of felt or other thick stuff being laid upon the seeds. The seeds belong probably to the *Chenopodium album*. They are lenticular, hard, of a shining black colour, farinaceous within, about the size of a poppy-seed, and are sometimes used to represent the eyes in wax figures.

The skin is exposed to dry in the shade, with the seeds indented into its surface; after which it is freed from them by shaking it, and beating upon its other side with a stick. The outside will be then horny, and pitted with small hollows corresponding to the shape and number of the seeds.

In order to make the next process intelligible, we must advert to another analogous and well-known operation. When we make impressions in fine-grained dry wood with steel punches or letters of any kind, then plane away the wood till we come to the level of the bottom of these impressions, and afterwards steep the wood in water, the condensed or punched points will swell above the surface, and place the letters in relief. Snuff-boxes have been sometimes marked with prominent figures in this way. Now shagreen is treated in a similar manner.

The strip of skin is stretched in an inclined plane, with its upper edge attached to hooks and its under one loaded with weights, in which position it is thinned off with a proper semi-lunar knife, but not so much as to touch the bottom of the seed-pits or depressions. By maceration in water, the skin is then made to swell, and the pits become prominent over the surface which had been shaved. The swelling is completed by steeping the strips in a warm solution of soda, after which they are cleansed by the action of salt-brine, and then dyed.

In the East the following processes are pursued. Entirely white shagreen is obtained by imbuing the skin with a solution of alum, covering it with the dough made with Turkey wheat, and after a time washing this away with a solution of alum. The strips are now rubbed with grease or suet, to diminish their rigidity, then worked carefully in hot water, curried with a blunt knife, and afterwards dried. They are dyed red with decoction of cochineal or kermes, and green with fine copper-filings and sal-ammoniac, the solution of this salt being first applied, then the filings being strewed upon the skin, which must be rolled up and loaded with weights for some time; blue is given with indigo, quicklime, soda, and honey; and black, with galls and copperas.

Shagreen is also prepared from the skin of the shark.

SHALES AND MINERAL OILS. *Shale*, according to old writers on petrology, signifies any rock, no matter of what mineral composition, splitting into thin laminæ, and found in what they termed the secondary and tertiary formations. *Schist* was the distinguishing appellative of such rocks splitting up in thin layers, found in the primitive formations of the same authors. The characteristic features of the individual rock were usually prefixed. Thus such terms as mica-schist, talc-schist, alum-shale, argillo-bituminous shale, &c., originated. But though they are still retained, a wider stratigraphical knowledge has made the two terms synonymous. Maculloch, in his 'Classification of Rocks,' has shown that a shale may leave the fissile state to pass in the same geological section into the botryoïdal, mammillary, and even earthy conditions. There are arenaceous, argillaceous, calcareous, or ferruginous shales, according to the nature of the parent-rock; thus, red hæmatite and the organically-derived Tripoli slate may be both included under the generic term. Use in manufactures has given names to alum-shales, argillo- or calcareo-bituminous, or, better still, oil-shales.

Like petroleum, oil-shales are found in all geological formations, and they appear to accompany both it and limestone geognostically. Wherever fossils indicate conditions of quiet subsidence, and estuary or lake formation, the observer has come on a locality, *primâ facie*, good for the occurrence of either oil-shales or petroleum. Such conditions in geography appear to have alternated with those of a sudden change to deep-sea life throughout all geological time. The Scottish carboniferous system appears to have been formed under very favourable circumstances for the production of oil-producing materials. The Mountain Limestone, instead of attaining the magnificent proportions of Derbyshire or Northumberland, is represented usually by six thin beds of a few feet thick. The reader, casting his eye on a geological map of midland Scotland, will mark how comparatively small a space is occupied by the coal-fields proper; that they are, in fact, surrounded by a large area of beds marked off in the books as the subcarboniferous or estuarine Burdiehouse-limestone formation. This, the area proper of the shales, extends through the counties of Fife, Edinburgh, Linlithgow, Lanark, Renfrew, and Ayr. But the true coal-formation also abounds in oil-producing material. Very intimately associated with each individual coal-bed, the occurrence of shale above it, and blackband ironstone below it, also an oil-yielder, may possibly indicate a different mode of formation from that of the Newcastle field. The rich cannels found throughout the Scotch coal-fields proper belong to the category of shales rather than coals.

During the years immediately succeeding the expiry of James Young's patent, oil-works were erected over the area of the Scottish coal-field. But since the continued depression of this new industry caused by the large importation of American petroleum, many small works have been dismantled; and the trade is now principally in the hands of a few large companies, who carry on their operations near West Calder and Broxburn, in the immediate neighbourhood of Edinburgh, and in the vicinity of Paisley. The amount of material used is still very great. The Addiewell works are alone capable of utilising 1,000 tons of shale weekly. So much as 782,000 tons of shale have been consumed annually; resulting in the manufacture of about 10,000,000 gallons of burning-oil, 5,000 tons of paraffin, and about 600 tons of sulphate of ammonia.

The Torbanehill mineral, the substance on which Young worked his patent, is now exhausted. But the high price given for it by foreign gas-companies, as well as the demand from the same quarters for the ordinary cannels, and for the bastard cannel, technically termed 'rums,' which abound throughout the Scotch coal-fields, have placed all these substances out of the reach of the oil-maker. The shales of the lower fresh-water series were waste products before the advent of this new industry; but from their special chemical nature, they yield an oil more easily brought to the white standard in colour of American petroleum than the substances first employed in the manufacture of crude oil.

The probable organic origin of a shale or cannel.—The Kimmeridge shale yielded an oil which could not be deodorised. So though a newly-discovered Brora shale yields as much as 57 gallons to the ton, it may probably be used only for the purposes of patent fuel, owing to the phosphorus it contains, derived from the animals whose remains are in part chemically represented by its oleaginous contents. So also of abundant flagstone bituminous beds of the Old Red Sandstone of Orkney and the North of Scotland. The same difficulty has been experienced with the Canadian petroleum; though it is said that in this special material the art of the refiner has overcome the disagreeable odour.

The close proximity of coal and shale, often found in one section, is of great importance in diminishing the working expenses of a shale oil-work. In Scotland, oil-makers generally also mine their raw products.

What is a Coal?—A strict chemical definition of coal or its allies has as yet been attempted in vain. Use has hitherto ruled the distinguishing nomenclature of coals. From the anthracite to the cannel, a clear gradation may be traced. But here we reach a once much contested border-land, where the true cannel graduates into the shale. The advocates of separation of the celebrated Torbanehill mineral from the class of cannel coals mainly contested that, unlike these bodies, after the oil or gas had been taken from them, it left no useful coke containing an appreciable percentage of fixed carbon; its sole residuum is a useless mass of clay. The superior character of the American petroleum, as well as the high prices ruling for gas material, have caused cannels, lignite, peat, as well as many caking coals, to be disregarded as oil-producing materials. At the same time, the technologist should note the physical and chemical capabilities of such bodies for producing oils for other than domestic uses. Dr. Eveleigh has proposed to manufacture gas from oil distilled first from ordinary coal by a special apparatus. Messrs. Odling and Keats, in reporting on this process for the Patent Gas Company, state that in their experiments, silkstone coal gave 16·4 gallons of tar and oil per ton; Clay cross main, 11·9 gallons; and Pelaw main, 13·9 gallons: or a mean of 14 gallons. They obtained from one ton of coal 9,500 cubic feet of 23-candle gas, and from 14 gallons of oil the produce of this 600 cubic feet of 25-candle gas. Though the American oil-wells may be said to have shut up the peat-works of the Continent, lignite is distilled there often specially for the extraction of paraffin.

A natural transition from petroleum to shale is exhibited, for instance, in the extensive gum-beds near Hamilton, Canada West. The viscous asphaltum may be only the fluid native naphtha changed by atmospheric oxidation; and, at least, some beds of anthracite may be only farther steps in the same series of changes. Attempts to extract their proximate constituents from these bodies by solvents have been as fruitless as those made on coals. Indeed, the recent experiments of Berthollet appear to show that the various hydrocarbons of coal-tar, and probably those also in crude shale oil, do not exist individually in the materials whence those bodies are extracted, but depend on different temperatures applied in distillation. By synthesis, Berthollet obtained benzine from acetylene; ethylene from acetylene and hydrogen; styrolene from ethylene and benzine; and naphthaline from ethylene and styrolene. Inversely, by the application of a red heat on toluene, xylene, and cumene, they were decomposed into hydrogen, formene, acetylene, ethylene, benzine, toluene, xylene, cumene, styrolene, naphthaline, anthracene, and chrysene. The gas-maker notes a strange individuality in the yield of special materials. The Newcastle coal-tar abounds in naphthaline; the Wigan cannel is specially rich in benzine and carbolic acid. So the oil-maker prefers crude tar from the lower carboniferous shales; specially, because they give a white odourless burning-oil; though other crude oils are cheaper, yield more paraffin, or may better suit applications to patent fuel, metallurgy, or gas-making. Probably more accurate knowledge of the different effects of heating in this manufacture may enable the oil-maker to extract equally good tar from any oil-yielding material; and likewise to obtain in gas-making from shales all the peculiar products of cannel coals.

Oil-shales, like cannel coals, have a yellow-brownish streak; are easily cut with a knife; and often exhibit a subconchoïdal fracture. The 'curley' bands have a black glossy external appearance; and are curiously bent into a series of corrugated foldings. They yield most oil; and are usually mixed with thick seams of poorly oleaginous shales. In some parts of Linlithgowshire, these shales are changed into a kind of black chalk; apparently in consequence of the trap rocks.

What are Mineral Oils?—To understand mineral oil-making, it is necessary to consult some good table of temperatures, such as Pouillet's.

The black heat or low-red heat of oil-making ranges betwixt 500° and 900° F., while the full cherry-red or dark-yellow red heats, so necessary in coal-gas manufacture, exceed 1000°. Shale-tar floats on the surface of water; whereas, coal-tar being of a higher density, sinks in it. Crude mineral-oil may be as high as 940° in sp. gr; but the shale-tar preferred for oil-making usually ranges from 840° sp. gr. to 890° sp. gr.

Crude-oil is really a series of oils held together by links destroyed in distillation. But the separate oils may be variously utilised, in accordance with their several physical and chemical properties. Yet, as they all are hydrocarbons, they cannot take the place of oxygenated oils of animal or vegetable origin used by painters or soap-makers. Mineral turpentine, the only apparent exception, is used by varnish-makers, not from its drying properties, but from its speedily evaporating altogether out of the paint-solution in which it was mixed.

Mineral oils in lamps.—They were first introduced as illuminants along with the now familiar German lamp; and they have largely displaced lamps using other vegetable or animal oils from their greater convenience, and from the superior brilliancy and cheapness of the light given. Olefiant gas mainly is thus given in the remotest hamlet, under circumstances of the easiest management. From the vaporisable nature of the oil, a lamp is supplied surpassing most previous similar contrivances in photogenic power. Continued application of ingenious minds has reduced the glass nuisance to a minimum, whilst it is now the fault of the purchaser should he employ a dangerous oil. Dr. Frankland gives the following results of experiments of the quantities of different bodies necessary to give the same amount of light, disregarding luminosity:—

Young's paraffin oil	4·53 litres.
American petroleum, No. 1	5·70 "
" " No. 2	5·88 "
Paraffin candles	8·42 kilos.
Spermaceti candles	10·37 "
Wax "	11·95 "
Stearine "	12·50 "
Tallow "	16·30 "

Dr. Macadam ['Royal Scottish Society of Arts,' vol. viii. 1871] compared the photogenic power of mineral oil with its animal and vegetable rivals with the following results:—

	Time of burning	Candle-power	Cost
	hours		d.
Halfpenny dip or tallow candle	3	1¼	½
Three-farthing " "	4½	1¼	¾
Penny " "	6	1¼	1
Composite candle (average)	5½	1·1	1
Paraffin candle (average)	4·27	1·49	1
Common flat-wick lamps:			
Sperm oil	3·59	1·306	1
Rape "	6·84	1·05	1
Whale "	9·5	·9	1
Argand lamps:			
Sperm oil	·69	13	1
Rape "	1·25	11·33	1
Whale "	1·57	9·8	1

In a cottage-lamp, paraffin-oil at 2*s.* per gallon burned for 9 hours with a luminosity of 6-candle power for a 1*d.*, and in a parlour-lamp this oil burned for 6 hours, giving 9-candle power for the same price; while it burned the same money value in the dining-room lamp in 4½ hours giving 12-candle power.

In setting it against coal-gas, Dr. Macadam assumes the high candle-power given by Scotch gas companies, and he takes a moderate price which is not now likely to prevail. Assuming gas to sell at 5*s.* per 1,000 cubic feet, and to have a luminosity of 28 candles, he finds gas cheaper than paraffin oil, if consumed at No. 3 jet; but should gas cost 5*s.* 8*d.* per 1,000 cubic feet, the two illuminating agents are equal. When this high candle-power of gas is withdrawn they are also equivalent in price and luminosity. Paraffin oil is as cheap as gas when the latter is consumed at No. 3 jet, and its cost is 5*s.* per 1,000 cubic feet; while its luminosity is 24·70-candle power; or at No. 4 jet when the same-priced gas is of 21·53-candle power; or at No. 5 jet when it is only 20-candle power.

Silber proposes to burn oils in rooms from permanent pendants, just as we do gas; and with special contrivances for the purpose has attained very marked results. ['Journal of the Society of Arts,' vol. xix. p. 88.] Using petroleum of sp. gr. 795 he obtained an illuminating power perhaps 20 per cent. greater than the London coal-gas, which is given to the consumer at from 12 to 15 candles; though with gas at 3*s.* 9*d.* per 1,000 cubic feet the cost of petroleum was 10 to 20 per cent. greater than the gas. But by an alteration in the argand the illuminating power was increased from 40 to 50 per cent. more than at first. So though colza lamp costs five times as much as the gas; Valentin's experiments gave with Silber's lamp a light equivalent to a saving of 500 per cent. Mr. Silber is now adapting his lamp to use the heavier and safer mineral oils. See SILBER LIGHT.

Use of mineral oils in gas-making.—It has been proposed to use mineral oils in gas-making either by naphthalising the poor gas made from ordinary coal, or by the conversion of the rich, oily hydrocarbons into permanent gas.

1. Beautiful results have been obtained by passing the gas through oils, whether of heavier or lighter specific gravity. The objections of smell, and the tendency of oil to return to its original state, have militated against the extensive use of this method in domestic circles. It appears generally necessary that the carburetter be as close as

possible to the gas-jet. A modified carburetter has been successfully employed close to the burner on the Edinburgh street lamps.

2. The conversion of oil into a permanent gas long baffled inventors. The fact, too, that when oil was so decomposed it usually deposited much of its carbon as coke on the sides of the retort, was a standing difficulty. Many modifications of water-gas, to be introduced so as again to take up this carbon, and also to supply cheaply an additional volume of gas, were usually proposed. The patent records contain many fruitless schemes; but Messrs. Keats and Odling report that by Dr. Eveleigh's process, worked out by the Patent Gas Company, a permanent gas has been formed singularly free from impurities, and of 25-candle lighting power. The present position of gaswork economics do not, according to these gentlemen, warrant the hope that the process will be extensively used in large cities, but it may be available in the country and abroad.

The rising value of cannel coals has induced gas-makers to inquire whether mineral oils might be used as sources of auxiliary supply in ordinary gas retorts, whether admitted *per se*, or made into a patent-fuel composition. Mr. Cussiter, of Dalkeith, when introducing oil alone into a retort, obtained in one experiment 15,904 cubic feet, and in another 18,600 cubic feet, with respective illuminating powers of 38·5 and 23·55 candles. The illuminating power in another experiment was only 12 candles, but the yield increased to 28,300 cubic feet. When 30 gallons—or 284 lbs.—of oil were mixed with splint coal in a clay retort, the yield was increased from 10,000 to 12,500 cubic feet, and the illuminating power from 14 candles to 25·89 candles. When 42 gallons of oil were used with 1 ton of coal, 13,140 cubic feet of 28·59-candle gas were obtained.

As we have already seen, shale is very widely distributed throughout the geological formations; and shale, which is useless for oil-making from poorness of yield and probable organic origin, may be used for gas-making. Specially should the gaswork be planted where the shale is mined, and the manufacture led in by pipes to the town where it is to be used. During the winter of 1872 many Scotch gas companies used ordinary oil-shale brought into their works from a distance.

Paraffin and petroleum residues have been utilised in small gasworks supplying railway-stations or private residences in Germany. The stuff is pumped up by clock-work into a retort capable of making 200 cubic feet of gas in an hour, which contains only 0·69 per cent. of impurities in the hundred parts. The gas consists chiefly of acetylene; and it is burned from jets consuming per hour from a ¼ of a cubic foot to 2 cubic feet; but 200 cubic feet of this gas equal 1,000 cubic feet of coal-gas. Convenience rather than cost of material instigates the erection of such works.

Petroleum has been successfully employed in small towns and villages of Canada and the United States for gas-making. The method usually adopted is to mix its vapours with that of water passing over red-hot charcoal or iron. Youle, Hind, and Thomson found 10 cubic meters of the gas equal in intensity and cheapness to 40 cubic meters of coal-gas. Besides, the manufacture consumes much less time. See NAPHTHA.

Mineral oils as liquid fuel.—The proposal to use such oils for raising steam excited great interest when first proposed. Many contrivances were patented and experiments undertaken, though without the happy issue anticipated. The following *résumé* of our knowledge on this subject is mainly derived from the evidence of Dr. B. Paul given before the Royal Commission on Coal Supply.

The materials which have been suggested as fuel are: Petroleum in a crude state, with a specific gravity from 800° to 860°; crude paraffin oil of sp. gr. 860° to 900°; heavy oils, the waste products from the distillery known as 'bottoms,' 'foots,' &c.; dead oil, or creasote of coal-tar distiller, sp. gr. 1050°. All these substances are much more highly inflammable than coal. Crude petroleum and paraffin-oil stand at the top of the list in this respect; dead oil at the foot.

	Weight of 1 cubic foot	Volume of 1 ton
	lbs.	cubic feet
Crude petroleum . . .	from 49·8 to 53·5	44·97 to 41·86
Crude paraffin-oil . . .	53·5	41·86
Heavy oil from either . . .	56·0	40·00
Coal	from 52·0 to 60·0	43·07 37·33

The next table shows the calorific power and evaporative efficacy of liquid fuel as compared with coal.

For 1 pound of	Total quantity of heat generated	Quantity of heat available for producing steam	Quantity of water heated from 60° to 212° F., and converted into steam at 212° F.	Temperature of flue or flame
	heat units	heat units	lbs.	°
Crude petroleum . .	20,000	16,847[1]	15	4646
Crude mineral oil .	20,000	16,847[1]	15	4646
Heavy oil from either .	20,000	16,847[1]	15	4646
Dead oil or creasote .	16,628	14,567[1]	13	4495
Coal . . .	from 13,890	10,000[2]	8·95	2500
	to 14,833	10,817	9·67[3]	

Thus oils may effect a saving of from 35 to 40 per cent. of the space occupied by a coal of equal steam-producing power. Not only would more space be available for cargo, but also fewer hands would be required. And in war-ships, steam would be more quickly raised; they could sail without smoke, and could keep to sea for a longer time. But against this, most of the oils proposed to be employed give off vapours even in the cold; and these, when mixed in certain proportions with the atmosphere are violently explosive. Then relative price must always be a great stumbling-block in the introduction of this new agency; when coal rises to *5l.* or *6l.* per ton the average prices of crude mineral oil or petroleum, the question will be a practicable one. Improvements in retorts, cheapening the cost of crude mineral oil, will also obviate this difficulty. [See PARAFFIN.] Creasote, estimated as worth 22*s.* per ton, has been advantageously used as a liquid fuel.

To use liquid fuel effectively, perfect combustion immediately under the steam-boiler must be obtained, so that smoke is prevented and the full heat or evaporative capacity of the fuel realised. The best coal-oils rarely contain more than 30 per cent. of volatile matter; but in those most suitable for steam fuel the quantity is very much less.

Richardson's method of applying liquid fuel was tested at the Woolwich Dockyard on July 6, 1866, under the supervision of Mr. Lloyd, engineer-in-chief of the Navy. The *rationale* of this plan is to employ steam-jets with the application of liquid fuel below the steam-boiler. In these trials much smoke was produced, and the tubes of the boiler rendered very foul by deposition of soot in them. The average results gave an evaporation of 13·2 lbs. of water per 1 lb. of oil consumed; the variations ranged from 7·14 lbs. to 18·38 lbs. of water; treated from 100° to 212° F.; and converted into steam at 212° F. In the most successful trials the evaporation was very low. Now average results have been obtained with coal of an evaporation of 8 lbs. of water to 1 lb. of the fuel, and much higher figures are not exceptional.

In Field's improved method, the oil flowing from a reservoir is projected into the heating furnace below the boiler along with a jet of high-pressure steam, introduced in the form of spray. As many as 19 lbs. of evaporative power have been quoted as the fruit of this patent, but 13 to 16 lbs. of water evaporated per lb. of oil consumed, are likelier figures.

By Dorsett's patent the oil is first vaporised before entering the heating furnace;

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[1] It is assumed that these oils are burned with only just enough of air for the purposes of combustion, and that the furnace-gas is discharged at 600° F.

[2] The coal is burnt as usual, with twice the air necessary for combustion.

[3] The evaporative duty given in the above and subsequent table is probably higher than that actually obtained on an average in steam-vessels to the extent of 20 per cent.; the actual duty obtained being usually seven pounds of water converted into steam per lb. of coal.

The following table exhibits the relative efficacy of liquid fuel and coal as steam fuel, in relation to the space they occupy respectively:—

1 cubic foot of	Quantity of water heated from 60° to 212° F., and converted into steam at 212° F.	Relative steam producing capability of a given bulk of fuel	
	cubic feet		
Crude petroleum evaporated . .	from 11·95 to 12·85	1·58	·91
Crude mineral oil	„ 12·84 „ 13·44	1·63	·96
Heavy oil from either	„ 12·84 „ 13·44	1·63	·96
Dead oil from creasote . . .	about 13·60	1·68	1·00
Coal as stowed in bunkers . . .	from 7·48 to 8·64	1·00	·59

and while it is being burned under the boiler, the elastic force of heated vapour is made to produce a blast of air so as to ensure perfect combustion. This was first applied in a coal-tar distillery. The time for running a charge of tar through the stills was thus reduced from 24 to 12 hours. And the stills so fired do not require so frequent repairs as those worked with coal. Indeed, such applications of heavy oil appear to be very economical. In Mr. Miller's Works, Rumford Street, Glasgow, a ton of dead oil, valued at 1*d.* or 2*d.* per gallon, appears to do the work of 1½ ton of coal at least.

In certain metallurgic operations at Woolwich, about 8 cwts. of liquid fuel were found equal in value to a ton of coal. One-fourth or one-fifth of the time occupied in heating with coal was saved, and a smaller number of furnaces were required. In heating a half-inch plate, 4 or 5 minutes served with liquid fuel in opposition to 15 or 20 minutes with coal. While a four-inch armour-plate took 3 hours in heating with coal, a very much better article was completed in 38 minutes with liquid fuel.

The different Mineral Oils.—The nomenclature of mineral oils is very obscure. It has partly originated from scientific discoverers; partly from tar-distillers who have been struck by the similarity of the educts from retorts or stills to those with which they have been familiar; and partly from the trade-marks of merchants. Eupion, photogen, kerosene, Cambrian oil, shale oil, Boghead naphtha, shale-naphtha or oil, paraffin oil, coal oil, are all synonymous for the article used in the German lamp. Then, again, all oils too high in sp. gr. to be used in such lamps were ranked as lubricating. But recent improvements in lamps for burning these heavy oils have caused the intermediate oils, betwixt 830° and 880°, to be sub-classed as lamp oils, lighthouse oils, railway-carriage oils, according to their several specific gravities. Blue oils or green oils are the refiner's terms for certain of his intermediate products which used to be in demand by grease-makers or printing-ink manufacturers. He describes other bye-products, as soda-tar and acid-tar; but we are in ignorance as to the true chemical nature of these bodies. Hard and soft paraffin correctly enough describe the solids sold respectively to the candle- or the lucifer-match-maker. 'Foots,' 'bottoms,' or such like names, have been borrowed from the tar-distiller to signify the refuse products of the stills. 'Scales' expressively denotes the paraffin pressed from the blue oil, to be subsequently refined. 'Naphtha' incorrectly designates the first product of the distillation of coal- or shale-tar, as the aniline-maker cannot find in the latter benzol, the foundation of his specialty. 'Coke,' however, truly describes a valuable bye-product obtainable at several stages of mineral-oil refining.

The prefix 'paraffin,' either to the lamp-oil or to mineral machinery-oil, is a misnomer, as there is none of that substance in either of these bodies. The proximate constituents of petroleum are the paraffin series; but mineral oils only contain $\frac{1}{6}$th or $\frac{1}{9}$th of these, their chief constituents being the olefiant-gas series.

Shale-tar, a local designation for crude oil, is correct enough when limited to the products of destructive distillation by a low red-heat, of sp. gr. 840° upwards. But a tar sinking in water might be obtained by the application of a bright cherry-red heat in distilling shale; and the converse is true of coal. The following scheme expresses to the eye the order of production of the various products:—

Yield from distillation of Crude Oil obtained from Coal or Shale, or from Petroleum got from natural Springs.

1. Light Oils or Spirits. 2. Burning Oils. 3. Heavy Oils.	Treated with acids and alkalis yield	Rectified Spirits or Benzine. 1. Burning Oil. 2. Acid Tar Residues. 3. Soda Tar Residues.
Heavy Oils rectified, besides yielding 2 and 3 residues.	1. Crude Paraffin. 2. Blue Oil.	1. Refined Paraffin. 2. Machinery Oil.

Residues may be used for greases, gas-making, patent fuels, &c. Gases may be used for heating.

Except in the case of the crude oil, which is of a dark greenish, viscous nature, analogous to tar, of the intermediate blue and green oils, which are sufficiently designated by their appellations, all the liquid products are now made as near water-white as possible. A burning oil is reckoned perfect in colour not only when it attains such purity, but when it also has the bluish opalescence so characteristic of refined petroleum. No doubt refiners here pander to a popular prejudice; for in striving after this standard of colour they diminish the burning qualities of their oils.

The merit of the common German lamp, whose introduction rendered these oils capable of domestic use, is in the introduction of so much air as thoroughly to consume the very great amount of carbon disengaged in their combustion. The sp. gr. 830° appears to indicate the highest number, in weight of the oil, capable of being consumed with comfort in such lamps. But inventors, such as Doty and Silber, have striven with some success to utilise the intermediate oils up to 888°, the recognised standard of superior mineral machinery-oil. All such oils possess higher luminosity and safety. The varied lamps for these purposes differ from the one used for common burning oil in admitting more air, so as to counteract the soot caused by the greater amount of carbon disengaged; and in adapting the shape of the lamp and the wicks, so as to cause those heavier oils easily to ascend them. The refiner is content to give all such higher oils a lemon-straw colour. So, in a very general way, it may be said that specific gravity and flash-point are the distinguishing features of the different products of destructive distillation at a low red heat. The relative figures of the hydrometer only may be taken as distinctive approximations of these different oils.

	Specific gravity	Flash-point
	°	° Fahr.
Crude oil	860 to 890	75
Mineral spirit	740 „ 800	68 to 75
Burning oil	810 „ 825	115 „ 125
Intermediate	830 „ 840	293
„ railway lamps	850	...
Lubricating	888 to 890	320

Lubricating Oils.—Dr. Wallace reports that in nine experiments on lubricating oils there was a varying specific gravity from 881° to 900°; and the flash-points ran from 293° to 388° Fahr. In seven experiments the flash-point was over 300° Fahr. As with the lighter oils, specific gravity is no *à priori* test of safety. The highest specific gravity amongst the samples 900° had the comparatively low flash-point 309°: another sample 20° in sp. gr. below this was only minus 1° Fahr. in flash-point; whilst another sample, 10° in sp. gr., below the first was 19° Fahr. in flash-point above it. The following are the specific gravities and flash-points of some well-known fatty oils:—

	S. G.	F.-P.
	°	° Fahr.
Whale oil (best)	923	492
Cloth oil (wool oil)	917	320
Olive oil	917	420
„ (genuine)	920	500
Rapeseed oil	913	440
Lard oil	914	560
Tallow oil	915	490

Mr. Gellatley's experiments on cotton-waste steeped in various oils ('British Association Report, 1872') appear to show that where a liability to high heats exists in using machines, mineral oils are safer than the older ones. Manufacturers are painfully aware of the liability to spontaneous ignition of cotton-waste which has been soaked with such a rapid oxidiser as linseed oil. Again, at a particular stage of calico-printing with Turkey-red, the batch is saturated with olive oil; and it cannot be allowed to lie for more than an hour without danger of spontaneous ignition.

For a discussion of the firing-points of burning oils, and their relative dangers, see NAPHTHA.

Preparation of Crude Oil.—When beginning the manufacture near Bathgate, Mr. Young used Torbanehill mineral as his raw material, though he was previously aware that any cannel would equally have served his purpose. But by the competition of gas-makers they have withdrawn all such bituminous substances from the oil-maker's market (see PARAFFIN); and even shale is now subject to a similar rival element. Shale is distilled in either horizontal or vertical retorts of cast iron. The charge of the horizontal retort is made in either the twelve or twenty-four hours, and varies from 6 to 12 cwts. Vertical retorts hold about a ton of shale, but are continuous; the charge is fed through a hopper at the top, and drawn out at the foot when exhausted, above a tray filled with water. Machinery has been introduced in some Scotch works for filling and discharging the retorts. With horizontal retorts it is not requisite to break the shale into small pieces the size of a hen's egg as specified by Young. A Carr's stone-breaker usually effects this for the vertical retorts. Scotch makers reckon steam as an indispensable adjunct in the distillation of crude oils. Experience has proved Torbanehill mineral to give 120 gallons per ton with steam; and only 90 gallons without it. Shale yields 40 gallons with steam, and 30 gallons without it. The difference in yield of finished products is 75 to 76 per cent. of the two crude oils respectively manufactured. In vertical crude the proportion of mineral spirits and burning oil is less than in horizontal, but 3 per cent. more paraffin is obtained.

Purification of the Crude Oil.—The crude oil issues as vapour into the condensers; it pours out at their extremity, as a mixed liquid of oil and water, into the separator. This is a wooden cylinder, 4 feet high and 3 feet broad. Through this barrel an iron syphon passes; this emerges at the side, a few inches from the top, and terminates about 8 inches from the bottom. The ammonia-water soon sinks under the crude oil, with which it is mixed on entering, by its higher specific gravity; whence it is drawn off by the above syphon. Almost at the top of the separator is another aperture, to serve as an educt for the crude oil.

The ammonia-water is next converted by the usual manufacturing methods of stills and evaporating-pans, into sulphate of ammonia. Some shales yield 8 to 10 lbs. of the sulphate per ton, whilst others give as much as 16 lbs. to the ton.

The crude oil is now transferred to the refinery by one of the series of underground pipes, in connection with the centrifugal pump worked by steam which now forms so integral a part in the economy of the establishment. The oil refinery, with tanks in which centrifugal revolving-stirrers, often only 2 feet in diameter, move by steam in iron vessels 10 feet in diameter, and agitate the oil with either sulphuric acid or soda. About 200 revolutions are made in a minute, and so a quarter-of-an-hour's agitation of the oil serves, instead of the night's work of early refining. There are also settling tanks, and a series of iron-pipes, which connects the oil with the stills outside, introduces the vitriol and soda used in purifying, or removes the vitriol and soda tars from the treated oils; all are subordinated to the main steam-pump. Indeed, throughout the varied processes the steam-engine as much as possible supplants mere manual toil; intelligent superintendence being only required from the few artizans on the establishment. The paraffin-house is usually distinct from the oil-refinery; it may contain only presses for making 'scales,' or the varied apparatus for the manufacture of refined paraffin. In either case, if the establishment is large it is associated with cooling-drums and an ice-machine, all of which, along with the presses, are worked by steam-power. In many large refineries the mineral spirits are refined in a separate building in connection with the paraffin-house. This is for greater safety from fire, which is sedulously guarded against by the adoption of iron doors, roofing, prohibition of smoking, use of covered lights, and such like appliances, throughout the entire establishment.

The following is a diagrammatic sketch of the various distillations of crude oil in its manufacture into burning oil:—

CRUDE OIL FROM SEPARATOR.

FIRST DISTILLATION.

Once-run oil.	*Coke in Bottom of Still.*
20° lower in sp. gr. than crude.	7 per cent. of oil converted into this, used as fuel, or drawn off as tar for patent fuel.
First Washing.	*Second Washing.*
5 per cent. brown vitriol, sp. gr. 1·745. May stand over a night in tank.	4 per cent. caustic soda, sp. gr. 1·300. Stirred for an hour.

SECOND DISTILLATION.

Third Washing.	*Fourth Washing.*
1 per cent. ordinary commercial vitriol.	2 per cent. caustic soda, sp. gr. 1·300.

THIRD DISTILLATION.

Fifth Washing.	*Sixth Washing.*
½ per cent. ordinary commercial vitriol.	½ per cent. caustic soda, sp. gr. 1·300.

Product.—Ordinary burning oil.

FOURTH DISTILLATION.

Seventh Washing.	*Eighth Washing.*
2 to 3 per cent. commercial vitriol.	With very dilute caustic soda.

This last product, termed *white horse oil*, is sold in competition with the American petroleum.

Cast-iron stills are still preferred by some for the first distillation; but the subsequent ones are usually performed in large malleable iron boilers of about 4,000 gallons capacity.

Refining Mineral Spirits.—Much care is requisite in separating oils which issue from the stills of such varied specific gravities. Were the light mineral spirit, or 'naphtha' of the works, to enter largely into either the burning, or at all into the lubricating oil, then would perish their reputation for safety.

The naphtha is first sent over by steam from the boiler, containing oil in the second stage of distillation. After being treated with $\frac{3}{4}$ per cent. of sulphuric acid, and neutralised with alkali, it is distilled again, by steam this time, at 13 lbs. to the square inch, and conducted by pipes down the sides of the still filled with naphtha, but playing freely into it through punctures in the pipes covering the bottom. The liquid is now ready for use in the paraffin-house, or for the special purposes to which it has been applied in various arts.

The Separating-house and Pressure-stills.—At Addiewell the contents of all the stills are conducted into a separating-house, containing 15 separators, leading to as many tanks outside. Here a man, by the aid of hydrometers, sends the oils into these varied receptacles, according to their specific gravities. Until lately burning and lubricating oils were the two marketable products, and the question rose, How to utilise the great quantity of intermediates? As a result of elaborate laboratory experiments, the application of pressure to oils was found to diminish their gravity; so pressure-stills have been introduced. A pressure of 15 lbs. on the square inch diminishes the specific gravity 30°. Thus intermediate oils can readily be converted into burning oil. Large malleable iron stills, with pressure-gauges and loaded safety-valves, with likewise a valve at the neck of the still, are employed for this purpose. The pressure on the oil-vapours themselves answers; hence when the still is put in action the valve is turned on at the neck, and the fires beneath well stoked till the pressure required is indicated on the gauge, when the oil-vapours are allowed to flow into the condenser.

Messrs. Henderson and Cooke have been able to dispense, at Oakbank, with the tedious process of settling and its multitudinous tanks, by simply agitating the oil, after it has come from the soda stirring-tank, with ground-glass or fuller's earth. This process is patented.

Preparation of Lubricating Oil and Paraffin.—The blue oils with paraffin scales are separated from the burning oil in the refinery after its treatment succeeding the second distillation, and pumped up into a tank on the roof of the paraffin-refinery. It is then sent through Henderson's cooling-drum, where the scale-paraffin crystallises out from the slobbery liquid. It is now subjected in canvas bags to two hydraulic pressures, whence commercial 'scales' are obtained, and heavy oil containing soft paraffin; this again is separated by ingress into another cooling-drum, where it meets a brine-solution of 22° or 24° Fahr., from Kirk's ice-machine. The soft paraffin is thus thoroughly taken out of its containing-liquid, which is now to be made into lubricating oil. It is subjected to a—

First Washing.	*Second Washing.*
2 per cent. of vitriol. Strength as before.	1 per cent. caustic soda.

DISTILLATION.

Third Washing.	*Fourth Washing.*
3 per cent. of vitriol.	1 per cent caustic soda.

It is then finished, though it is sometimes again distilled.

PREPARATION OF REFINED PARAFFIN FROM SCALE.

First Washing.	*First Cooling in Drum.*
$\frac{1}{3}$rd per cent. of its volume of hot naphtha.	

FIRST DRESSING.

Second Washing.	*Second Cooling in Drum.*
As before.	

SECOND PRESSING.

Third Washing.	*Third Cooling in Drum.*

THIRD PRESSING.

Tenth. Boiled with bone-black in jacketted steam-bath.

Twelfth. Filtered through Swedish blotting-paper in a steam-jacketted filter, and run into trays.

Thirteenth. It may again be boiled in a jacketted steam-still, so as to expel all odour of mineral spirits.

According to the price of candle wanted, the tenth process may succeed either the first, second, or third pressing.

From the washings which flow from the paraffin when under hydraulic pressure, soft paraffin, much used in lucifer-match-making, and burning oil, or spirits, for re-use in the process, are recovered. The spirits used must not be too light; those having a specific gravity of 745° were once used at Addiewell, but strong electric sparks were emitted from the cooling-drums; and hence there was constant liability to fires. A specific gravity of 765° may be safely used. For a new way of manufacturing this beautiful material, see the article PARAFFIN.

Kirk's Refrigerator, invented to meet Mr. Young's necessities in this manufacture, works on the principle that just as force is exerted air loses heat. By a series of pistons and plungers air is expanded, and then rarefied. During this rarefaction so much heat is extracted that a cold current, sufficient to form ice, is produced. Such machines are made to make 1 to 4 tons in the 24 hours. In the paraffin-refinery a solution of common salt in water receives the cold current; this is more easily manipulated than ice.

Henderson's Cooling-drum (Spec., A.D. 1870, No. 3310) is now preferred to that of Kirk. It is the instrument by which the cold current is applied to the paraffin, either in separating it from the lubricating oil or before bagging.

Most refineries recover the caustic soda from the soda-tar by the usual methods pursued in that manufacture. At Oakbank Works Mr. Henderson has an ingenious plan by which he first separates the vitriol used in washing the oils from the tars, to re-transfer it for use in manufacturing sulphate of ammonia. The now neutral tar is conducted by a pipe, within which is another containing steam, to the still-furnaces, and burned as fuel. It is first projected on a hearth above the ordinary furnaces where it is coked, and then allowed to fall down into the ordinary furnace. Half of the fine oil-stills are thus fired, and all the available tar is thus used up. The stills stand much longer than if they had been heated by ordinary coals. There is thus no just cause why oil-refiners should subject themselves to vexatious actions for river pollution.—A. T.

SHAMOY, or **SCHAMOIS LEATHER.** See LEATHER.

SHANGHAI OIL. A good oil obtained in China from the *Brassica chinensis.* See COLZA.

SHAWL MANUFACTURE. Shawls were originally, and still continue to be woven in the centre of India, from the fine silky wool of the Thibet goat; and the most precious of them still come from Cashmere. The wool is beautifully rich and soft to the touch, and is superior to the finest Continental lamb's-wool. It is also divisible into qualities. The source from which this article of apparel has sprung is well known to be the ancient and beautiful fabric of the valley of Cashmere, where the excellence of the raw material stands unrivalled, although its manufacture has been, and still is, carefully prosecuted in many other parts of the world. The great beauty of the eastern tissue, considering the rudeness of the machinery employed, as compared with that which is now available to the European manufacturer, is a marvel in the eyes of the most experienced.

The following information, which has been communicated (1874) by a well-known London firm, will prove of interest:—

'The importance of the London public sales of India shawls has greatly diminished of late years, owing to the establishment in Umritzir of agencies of the principal Paris shawl-dealers. Shawls are in consequence bought on the spot by these representatives of the Paris firms, and forwarded direct to their principals in Paris, thus escaping the London market. We continue to hold public sales twice a year, as usual; in June and December; but unfortunately, they are now for the reason explained above, shorn of much of their former interest and importance by the direct trading between Paris and the India shawl-districts; these French buyers naturally secure all the more desirable shawls, and those which are left, or passed over, are sent to the London sales. Some few years ago, say during the 15 or 20 years preceding 1862–3, the sales were of considerable magnitude and importance, and used to range in value from 100,000*l.* to 140,000*l.*, every sale: but after 1863, they rapidly declined, and ceased to be held during the Franco-German war; after that epoch we revived the sales, and they continue, but their value now is reduced to from 30,000*l.* to 40,000*l.* a sale, and contain *very few rich shawls.*

'The highest value of *Cashmere* shawls is from 100*l.* to 140*l.* each, *maximum cost,* and of the good ordinary Cashmere 40*l.* to 80*l.* There are no such prices as 10,000 francs for a shawl; such a price may have existed in bygone days, but not of late years. We have in exceptional times (in past years) obtained from 160*l.* to 220*l.*, per shawl for a few long shawls in public sale, but they were shawls of the grandest kind, and such as it would be impossible to obtain now. Furthermore, the competition among the shawl-dealers in Paris, Lyons, Bordeaux, &c., is so great that they work for close profits, and first-class shawls may be bought in Paris or in London for 2,500 to 5,000 francs in Paris; or from 100*l.* to 200*l.* here.

'Fashion is against shawls for the moment, since the introduction of the "costume" dresses, and they are hardly worn; this necessitates severe holding by the wealthy Paris dealers; we estimate the money value of shawls in the hands of the half-dozen leading Paris shawl firms, at the present moment at little, if at all, short, of half a million *sterling*.

'During the Franco-German war, shawls were hurried over to our care by the Paris dealers, for safety, and we received between 300,000*l.* and 400,000*l.* worth in this way. These were safely lodged at the Dock warehouses, and upon the return of peace, were sent back by us to the various owners in Paris; there was no pressure to sell them during all that time, the shawl-dealers being all wealthy men, and among the first merchants in Paris.'

The manufacture of shawls was first begun in this country, at Norwich, by Mr. Barrow and Alderman Watson, in 1784. They copied the Indian style, but the process was very slow, and the result consequently costly. Mr. John Harvey, of Norwich, followed up the enterprise with Piedmont silk warp and fine worsted shoot; but the designs were darned by hand. It was not until 1805 that a shawl was produced entirely by the loom at Norwich. In Paisley and Edinburgh the manufacture was introduced about the same time. At Paisley the manufacture is still continued, especially the manufacture of shawls of the Indian pattern, from real Cashmere wool. In 1802, a manufacture of shawls was commenced in Paris, and this led Jacquard to the invention of his loom (see JACQUARD LOOM), with which now all kinds of shawls are woven. For the mode of manufacture, the respective articles, SILK, TEXTILE FABRICS, and WEAVING will be sufficiently descriptive.

The varieties of shawls produced may be grouped as follow:—

Woven shawls of India, or of Indian style, made in Europe.

Barège shawls, made of wool: an imitation of shawls made in the Pyrenees, by the peasantry of a place so called.

Crape shawls, made of silk, in imitation of the Chinese fabrics.

Grenadines, made of silk of a peculiar twist.

Levantines and Albanians, made of silk and spun silk, to resemble the scarves worn in the Levant and Albania.

Chenille shawls; a novel application of silk, frequently combined with cotton.

Chiné shawls; a printed warp before weaving.

Woollen shawls; ordinary kinds.

Tartan plaids. The manufacture of these appears to be very ancient. In 1570, an ancient Scottish manuscript gives a list of the colours of the plaids worn by the different clans. In 1747, the weaving of this distinctive dress was prohibited by Act of Parliament, and the grey shepherd's mauds were made instead. In 1782, this Act was repealed; but tartans did not become fashionable until the visit of George IV. to Scotland, in 1822; after which, the Stirling fancy plaids began to be made. In 1828, clan-tartan shawls became fashionable, and the Galashiels weavers took up the trade. Paisley commenced to weave these shawls about twenty or thirty years ago, and it has since then extended to many other parts, both at home and in other countries.

SHEARING. See BLEACHING.

SHEATHING OF SHIPS. The process of coppering vessels has been generally adopted in order to protect their bottoms from the injurious effects of insects in hot countries, and to prevent the adherence of barnacles, &c., which greatly impede the progress of the vessels. It has, however, been open to objections, for not only is the prime cost of the material great, but the expense of rolling it into sheets, and the frequent renewal of parts which had been injured during the voyage, make this copper covering a serious item in the expenses attendant upon fitting-out ships.

In order to make the application of copper still more general, Sir Humphry Davy turned his attention to the subject, and endeavoured to devise some method of counteracting the rapid oxidation which takes place on its exposure to the sea-water, as it is rare for the copper-bottom of a ship to last longer than five or six years. Experiment proved to Sir H. Davy that if a portion of zinc were applied to the copper it would by its electrical relations prevent the process of oxidation in the copper. A vessel sheathed with copper and zinc plates was accordingly sent a voyage to a distant part of the world, from whence it returned with its copper perfectly uninjured by the salt water, but in as foul a state as if there had been no sheathing upon the bottom of the vessel. The presence of the zinc had prevented the oxidation of the copper which was necessary to resist the marine deposit. The problem, therefore, still remained to be solved, whether any metallic composition could be found for the sheathing of ships capable of preventing the bottom from fouling, and at the same time resisting the process of oxidation. To the solution of this problem Mr. Muntz, who was a metal-roller at Birmingham, directed his attention, and commenced a series of experiments, which resulted in his taking out a patent in 1832. This invention, slowly, but steadily, attracted the notice of the shipping interest of the country, and it appeared that in 1834, in the port of London, twenty ships were sheathed with metal prepared by Muntz's patent process. The number gradually increased, until in 1843 there were in the same port 257 vessels sheathed with the new composition, and now it is very generally used. The improved metal sheathing is a mixture of copper and zinc, which is cheaper than copper, more easily worked, and lasts longer than the pure metal. In the specification of Mr. Muntz's patent, the nature of his invention is thus described: 'I take that quality of copper known to the trade by the appellation of "best selected copper," and that quality of zinc known in England as "foreign zinc," and melt them together in the usual manner, in any proportions between 50 per cent. of copper to 50 per cent. of zinc, and 63 per cent. of copper to 37 per cent. of zinc, both of which extremes, and all intermediate proportions, will roll at a red heat; but, as too large a proportion of copper increases the difficulty of working the metal, and too large a proportion of zinc renders the metal too hard when cold, and not sufficiently liable to oxidation, I prefer the alloy to consist of about 60 per cent. of copper to 40 per cent. of zinc.' See MUNTZ METAL.

Various unctuous preparations and paints have been introduced for the purpose of coating the sheathing on the bottoms of ships. The secret of all of them is the presence of a metallic oxide which is offensive to both the vegetable and animal organisms.

SHELLS. Hollow projectiles filled with combustible materials. See ARTILLERY.

SHELLS OF MOLLUSCA. Many of these are used for ornamental manufacture. They will be found described under CAMEO.

SHERRY WINE. See WINE.

SHIFT. *A miner's term.* As used in Alston Moor and the Northern mines, a *shift* is the quantity of lead ore contained in six or eight waggons, and amounts to about 240 kibbles of 14 quarts each; each waggon in a six-waggon 'shift' contains 40 such kibbles; while in an eight-waggon 'shift' each waggon contains only 30 kibbles. In collieries a *shift* is the time during which the men work in the pit.

SHINGLING. Condensing the iron bloom by heavy hammers. See IRON.

SHODDY, properly so-called, is the refuse of the willowing and scribbling process in the preparation of mungo and wool, and is sold in large quantities for manure.

SHODEING. *Shodes* (related to the German *schutten*, 'to pour forth') are loose stones; applied to such as are of a mineral character. Shodeing, is tracing those loose stones from the valley in which they may be found up to the mineral lode from which they have possibly at some remote time been removed. In this manner many mineral lodes are discovered.

SIENNA. Clay coloured by the peroxide of iron and manganese. It is known as raw and burnt Sienna, according to the treatment it has received. It is a good artists' colour.

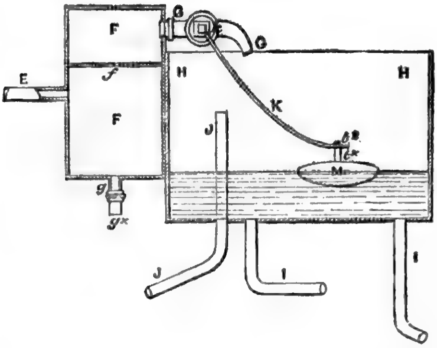
SILBER LIGHT. There is so much that is interesting in the progress of the inquiry, which resulted eventually in the production of the Silber light lamps that, we are pleased, at finding ourselves in a position to give a succinct record of that progress.

The first invention of interest dated from December 20, 1869, and is a method of indicating time at night. The figures of the hours are marked upon a glass globe, which revolves, by means of clockwork, around a stationary index. At night, any ordinary night-light is placed in a little glass tumbler which fits upon a platform, and is enclosed by a chimney, around which the globe revolves, the figures then being illuminated from within.

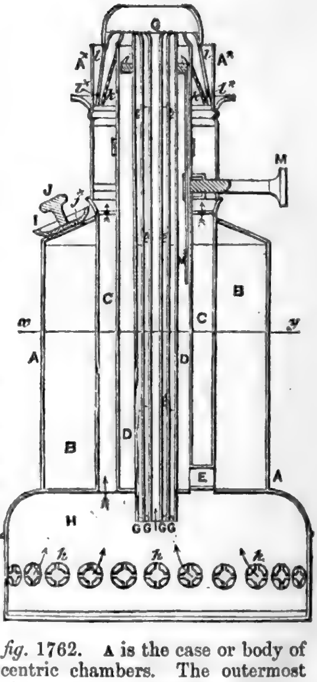
The lamp used for this purpose is constructed upon the moderator principle, but with a burner in which mineral oil may be used with safety. The moderator lamp could be used, but the disadvantages arising from the liability of its pumps and springs to get out of repair, and from the inconvenience of having to wind it up every four or five hours, led to a search for the means of maintaining the oil-supply at a constant level, not only in one burner, but in any number that might be required. In a patent dated May 20, 1870, Mr. Silber devised the following plan:—A ball-cock similar to those used in all water-cisterns, but with a china float, and a new joint which connects it with the elbow, and which, when properly constructed and adjusted, will work as correctly as a clock movement. The china float is not affected by either mineral, vegetable, or animal oil; and it overcomes the difficulty of producing a float which will act as readily on petroleum as on water, notwithstanding the lightness of the former, which is to water as 790 to 1,000. The china float is a circular double convex disc, pierced with a hole in the centre. Into this hole is fixed a piece of hard wood to which the arm or lever is attached by means of a metal pin.

By the means adopted, it is proposed to use any combustible oil, in a manner similar to that of gas, the oil flowing from a reservoir placed at some elevated point, and from it supplying any number of lamps. In the case of using petroleum or any easily inflammable oil, certain precautions particularised in the patent, are adopted. Sufficient for our present purpose to say that from the reservoir the combustible liquid is conducted (*fig.* 1761) to the receiving box H, through a branch pipe E, widened out into a box at F, and terminating in a tap G, that is to say, E, is a branch pipe, which leads from the cistern through the filtering box F and tap G, into the receiving box or chamber H. The box F and tap G form, in effect, portions of the service or supply-pipe leading from the main service; or, in other words, the branch E, box F, and tap G form a service or supply pipe. The filtering box F, which is connected with the branch E, is also attached to the back of the chamber H, and it contains a partition or diaphragm *f*, made of wire-gauze or perforated metal; *g* is an opening at the bottom of the box F (closed by a joint, nut, or screw cap $g^{\times}$) for removal of subsidence or deposit from time to time. G is a tap connected with and leading from the box F, and forming the termination of the service or supply pipe. This tap G leads from the box F into the chamber H. The pipe E opens into the box F below the partition *f*, and the tap G opens out of that box at a point above the partition *f*, so that the oil or liquid in passing from E to G is filtered by its passage through *f*. H is a vessel or chamber which contains a float-valve for opening and closing the pipe G. I is or are (one, two, or more) pipes, which lead from the vessel H, and communicate with burners *i*. J is an overflow pipe leading from the interior of the chamber H into the waste pipe. The oil or liquid in the tank will, by the law of equilibrium of fluids, flow through the branch pipe E into the filtering box F, and passing through the diaphragm *f* therein, it will rise into and flow through the tap G into the chamber H, the tap of pipe G being open, because the float hereinafter described will be depressed while the chamber H is empty, and it will rise when the chamber H is filled with oil or liquid to a certain level or height. From this chamber H the oil or liquid will flow through the pipes I and through the conduits communicating therewith (arms, brackets, pendants, as the case may be), to the burners where such oil or liquid is to be burnt and used for illuminating purposes.

1761



1762



In a communication made to the Society of Arts on December 21, 1870, Mr. Silber proposed by arrangements of this kind to light private houses, towns, or factories.

In the course of experiments upon combustion of petroleum, it was found that, by permitting the oil to remain below a certain level in the burner, a greatly-increased illumination was obtained with a diminished consumption of the oil, which is then vapourised in the upper part of the burner, before it reaches the flame, and is consumed at the top of the wick. By this method no residue is ever left in the burner itself.

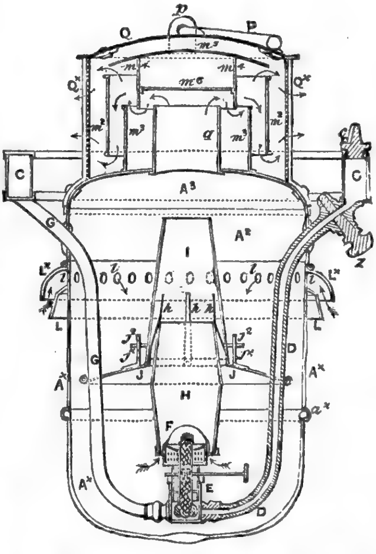
The arrangement of this burner will be seen in *fig.* 1762. A is the case or body of the lamp. The lamp contains a number of concentric chambers. The outermost chamber B contains the oil or combustible liquid to be supplied to the burner. C is a tubular or annular space into which air is fed and through which it circulates; it forms an air-jacket. D is the wick-case, that is to say, an inner concentric, annular, or tubular chamber, which holds the wick and which receives oil or combustible material from the chamber B, through the pipe E, which traverses the air-jacket C, and forms the communication between the chamber B and the wick-case D. The lower portion of the wick dips into the oil-supply through the pipe E from the chamber B. G are air-tubes inserted concentrically within the chambers B, C, D. They consist of tubes held by struts *t*. These tubes are preferably bell-mouthed at top.

It will be observed that the air-jacket C is interposed between the oil-chamber B and the wick-case D, so as to keep the oil and wick sufficiently cool and prevent the undue or immature evaporation of the oil.

Air is supplied to the air-jacket C and to the internal air-tubes G from a chamber H, which is in a space within the case A, at the foot of the lamp, which is supplied with air through orifices of plain or ornamental shape *h*, *h*, *h*. I is the feed-hole for supplying the chamber B with oil or combustible liquid; J is a screw-cap which closes the feed hole; $j^{\times}$ is an air-hole through the plug of the screw-cap J, forming a vent to the chamber B; *k* is a perforated conical cap surrounding the wick; *l* is a conical annular cap perforated only near the lower part, $l^{\times}$ also surrounding the wick. There are intervals for the passage of currents of air between the wick-case D, the cones *k*, *l*, and the outer shell or case $A^{\times}$ of the burner. M, $M^{\times}$, are the ordinary key and rack for raising and lowering the wick.

The next difficulty to be overcome was to produce a steady light, of a colour pleasing to the eye, and, at the same time, to secure the complete combustion of the oil employed. In the ordinary circular or Argand burner, the current of air produced by the flame passes so rapidly over the exposed part and surface of the wick, that it carries off with it much partially-consumed oil; and such a burner, if lighted for any length of time in a close room, very perceptibly contaminates the atmosphere. In the burners described, it will be observed that a tube or tubes are placed within the wick-case; and these tubes divide the current of air in the interior of the flame, and permit the atmospheric oxygen to mix freely with the carbon, not only at the top of the wick, but also higher up, about and above the centre of the flame. By this means a light of uniform white colour is obtained, and 3 inches high. Moreover, the insertion of tubes admits of an increase of the diameter of the burner. In this invention, the patentee claims two things: first, the conversion of the oil into vapour before it reaches the top of the wick; secondly, the admission of air by the inner tube, specially to the upper part of the flame, where it gives a fresh impulse to, and completes the combustion of volatilised matter that might otherwise be carried off unconsumed. The conversion into vapour is effected by separating the bulk of the oil from the wick-case, and by admitting to the latter only a few drops at a time. The heat generated by the flame is imparted to the metal at the top of the burner, and is thus communicated to the wick-case, where it at least partially volatilises the small quantity of oil contained therein.

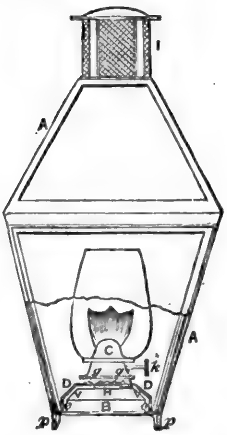
1763



Another patent, dated December 19, 1870, refers to a roof-lamp for railway carriages, in which the bulk of the oil is kept not only outside the lamp, but also outside the carriage, and thus nearly at the temperature of the air. In all previous roof-lamps the oil is contained within the lamp, and soon becomes greatly heated. $A^{\times}$, A^{2}, is the body of the lamp, which consists of two main portions, one fitting on the other. The lower portion $A^{\times}$ is the glass, or as it is technically called 'globe,' though it is not precisely of a globular form as ordinarily used. It is made of glass held in a metal frame $a^{\times}$. The upper portion A^{2} is of metal. Brackets are fixed to the body of the lamp, and project outward from the same. On these brackets rests an annular receiver or receptacle or oil-holder C, intended to receive the oil for supplying the burner of the lamp. This receiver C is therefore on the outside of the lamp, and its outer surface is thus bathed with the circumambient air, so that the oil in the receiver is kept at the temperature of such circumambient air, and is thus prevented from being unduly heated, whereby the danger hitherto apprehended from burning mineral oils in such lamps is prevented. *c* is a screw-cap, which closes the feed hole by which oil is admitted into the receiver C; D is a pipe by which the oil flows from the receiver C to a chamber or socket E, which holds the burner F. The pipe D passes from the outside receiver C into the body of the lamp. G is an arm connected at one end with the socket E, and at the other with the body of the lamp. It (as well as the pipe D,) supports the socket E. The burner F holds a wick, which at its lower end dips into the oil in the socket E, and thus receives its supply. The apparatus E, F, is shown as constructed in *fig.* 1763. H is a glass chimney held in a gallery or groove; I is a metal chimney which surrounds the chimney H to a certain height, and at a little distance from it. The chimney I protects the chimney H, and the flame, from sudden draught or currents of air. J is a reflector of silvered-copper, which throws the rays downward; it is connected with the pipe D by a bracket, and it carries little uprights $j^\times$, through which pass rods j^2 for holding the chimney I in place; *h*, *h*, are springs which hold the chimney H firmly, and prevent it from oscillating or being shifted out of place; Z, tap for regulating the flow of oil towards the burner; *l*, *l*, are air-holes in the part $A^\times$ of the body of the lamp; they receive air through a channel formed by flanges L, $L^\times$, which are in a piece with the body of the lamp; A^3 is a dome or cap, which surmounts the lamp, and has over it a cap Q, fixed on a perforated cylinder $Q^\times$, formed of perforated metal or wire-cloth, and having an interior space as shown; *q*, short air-pipe or chimney fixed in the cap A^3; m^2, m^3, m^4, concentric wind-guards or cowls for protecting the light from gusts of air, and for allowing the aëriform or fuliginous products of combustion to escape into the external atmosphere; m^6 is a diaphragm attached to the cap m^4, and acting as a deflector to guide the said products into the open air; m^5 is a cap attached to the cowl m^4, for guiding the smoke outwards; *p*, *p*, are lugs, through which pass the ends of a handle P, which are hooked. On the lugs are tails, which pass through the cap Q, and support the parts Q, m^2, m^3, *q*.

Another arrangement, patented July 31, 1871, relates to street, signal, and carriage lamps, and affords a means of keeping the oil-supply contained in them at the temperature of the atmosphere, by surrounding the receptacle with an air-jacket. By this means the flame is prevented from rising, and the lamps may be left burning, without any attention for 24 hours or more. The reason for not separating the bulk of the oil, as in railway roof-lamps, and inserting a small cup for present supply in the centre, is that the available space, in those now under consideration, is too limited for this purpose; and also that, in street lamps, the oil receptacle would cast an objectionable shadow. In all other closed lamps, in which mineral oils are used, the oil becomes heated, and upon this the flame rises and becomes smoky, diminishing the light, fouling the chimney, and increasing the consumption of oil very considerably.

1764



Another important point in all lamps intended for use in the open air, is to establish such an equilibrium within the lantern that no more air will find admittance than is necessary for the support of the flame, and that there shall be no disturbing down-draught from the top or sides. This is effected by the use of a top or cowl, which entirely excludes down-draught. Lamps fitted with these cowls, and with no other protection, have been in use in the carriages of the Metropolitan Railway, and on lines on which a very high speed has been maintained, and they have burnt quite steadily, the flame being absolutely unaffected by the motion.

Fig. 1764 is an elevation, partly in section, of a street lamp constructed according to Silber's invention. A is the case of the lamp, consisting, as is usual, of a glazed frame, one side of which forms a door, but the case is formed open at bottom instead of being closed as usual, the bottom of the oil-holder closing the case when the lamp is in its place within it. The lamp, which is detachable from the case, so as to be readily placed in it and taken out of it, consists of an oil-holder B, and a burner or wick-holder C, which is inserted in, and communicates with the interior of the oil-holder B. D is a jacket or casing, which is connected with the oil-holder B, by ties or struts at intervals, and which surrounds the oil-holder on all sides except at the bottom, and also except at a small portion of the top. The contour of the jacket or casing D follows or corresponds with that of the oil-holder which it surrounds. V is the space between the jacket and the oil-holder: it forms a space or passage for the circulation of air, which enters at the bottom this space or passage, and also through air-holes *e*, *e*, formed in the lower part of the casing D. H is a short tube, socket, or ferrule, fitted in the space V, and attached to the oil-holder B and casing D to receive the burner or wick-holder C, the wick passing at bottom into the oil-holder B. The burner or wick-holder C, with its key *k* and chimney, are of ordinary construction; *g*, *g*, are ordinary air-holes at the lower part of the shell of the burner. The lamp rests by the bottom edge of the jacket or casing D, on a ledge *p*, fixed on the inside of the frame of the case A; this ledge thus supports the whole lamp in the case, and the case is closed at bottom by the bottom of the oil-holder B, except at the space V left open between the casing D and the sides of the oil-holder B, for the circulation of air, which bathes the oil-holder as described, keeps it cool, and allows of the light being maintained equal and steady for a number of hours in the case or frame. Air-holes *e* may be sometimes formed in the sides, and sometimes in the top of the casing or jacket D, as well as in the lower edge thereof.

Improvements in gas-burners have been founded upon combinations already described for supplying the flame in the proper place with the precise quantity of atmospheric air required for complete combustion. The inventor of this light directs attention to the curious influence exerted by the height of the chimney upon the illumination afforded by a given quantity of gas. If the height of the chimney be increased from 5 to 10 inches, the light produced appears to the unassisted eye to be whiter and better for the change. But when accurately measured by the photometer, we find that the light is actually diminished by one half, and, at the same time, the consumption of gas is considerably increased. A similar influence is exerted by the shape of the chimney; for if we place the chimney of a common moderator lamp over a gas-burner the same result is obtained.

Experiment has also shown that there is no gain, as compared with an Argand in the employment of a double flat-wicked or 'duplex' burner. If we take a duplex-burner, each wick of a given width, and a circular burner of such dimensions that its wick, if cut in two, would be precisely equal to the two wicks of the duplex, and if we test both burners under the same conditions, their illuminating power and consumption will be found to be precisely equal. This simple experiment could not have been tried before the modern duplex-burner was perfected; for two separate flat burners, each with a single wick, show a totally different result. The bodies of the burners prevent the flames from being brought into sufficiently close approximation.

Many attempts have been made, all more or less unsuccessful, to burn oils or gas without a chimney, and to convey air to the burner through apertures somewhere in the lantern, and from thence through tubes or chambers to the flames. These attempts are thought by Mr. Silber to have been wrong in principle, because the air-tracks in all of them, however circuitous, have been continuous and unbroken. If we take a rigid tube of whatever form, and twist it into any number of turns or coils, and then blow into it, we shall find that the forcible exit of air at one end will be simultaneous with its forcible entrance at the other. In the same way, a lamp with a continuous air-track, if moving with a train or vessel, is exposed to sudden rushes of air upon the flame; and, even if standing still, similar rushes will be produced by alterations in the force or direction of the wind, or by any other atmospheric disturbance. The Silber lamp, in the first place, receives its air supply from above, and neither movement nor atmospheric disturbance exerts much influence on the rate at which air descends through an aperture. This rate is mainly governed by that of the escape of the hot air, which has its outlet within the circle of ingress of the fresh supply. The entering cold air is met, a few inches below the aperture which gives it admission, by a solid metal top or inner roof, which becomes heated when the lamp has been burning for a few minutes. A slit at one end of this inner roof allows the slightly-warmed and rarefied air to proceed onwards whenever it can find opportunity; that is to say, just as rapidly as the exit of the exhausted or consumed air makes room for it. On its course it passes over the receptacle in which the supply of oil is stored, and keeps this at a moderate and regulated temperature; then between this receptacle and the inner side of the outer part of the lamp; and, lastly, beneath the chamber to which the burner is fixed, from whence it finds admission to the flame. The height of the wick is regulated without opening the lantern; and these lanterns having no opening at their lower part, are especially valuable for use on board ship. You will observe that there is no possibility under this arrangement of a continuous current of air driven in any one direction, but that the air can only diffuse itself gradually, and in proportion to the room made for it, through a succession of chambers which effectually break up its continuity. Moreover, the capacity of the chamber is so calculated that no more air can enter the lantern than is required for the maintenance of proper combustion.

With reference to the cost of artificial light from oil, obtained by the Silber system, and compared with the cost of gas, we have the evidence of Mr. William Valentine, who says:—

'The principle involved in the construction allows of the burning either of mineral, vegetable, or animal oils, and of oils which hitherto have never been burnt to advantage, such as the so-called heavy mineral oils.

'The same principle is equally applicable to ordinary moderator lamps, with the additional advantage that largely-increased lights can now be constructed on the principle of the moderator lamp burning colza or mineral oils.

'The light produced by the burners constructed on these new principles is whiter and steadier than any light I am acquainted with; and the increase in the illuminating power, as compared with that from ordinary burners hitherto in use, is fully equal to from 40 to 50 per cent. without any increased consumption of oil.

'My experiments show that a light can be produced from mineral oils 40 to 50 per cent. cheaper than the same light from coal-gas, costing 3*s.* 9*d.* per 1,000 cubic feet.

'Experience has shown that the burning of properly-purified mineral oil has no detrimental effect upon animal and vegetable life.'

It is known that the volatilisation of colza or other vegetable oil cannot be properly effected if the oil is allowed to ascend in excessive quantity to the top of the wick. On this account, instead of allowing the oil to overflow the top of the wick-case, as it does in ordinary moderators, Mr. Silber drills holes through the case about a quarter of an inch below the top. The overflow in the Silber lamps takes place by means of these holes, and combustion is carried on with only a small portion of the wick raised above the case. By this arrangement also, the wick is preserved for a much longer time than when it is exposed to the atmosphere as in ordinary moderators.

Signal-lamps for railway and other purposes are constructed of two parts: the outer casing, or lantern; and the inner part, or lamp proper. Generally speaking, the lantern is a fixture, from which the lamp is withdrawn to be trimmed and lighted. In the Silber signal-lamp, the lamp proper is so portable that a man can carry three or four in his hands at once, either lighted or unlighted, in any weather. Whilst thus carried the lamp remains effectually closed; but as soon as it is in its place within the lantern, it is opened at the top by the falling of a self-acting handle, so as to allow the escape of the products of combustion. This self-acting handle is a very important matter, because it prevents mistakes, which frequently happen with other lamps, from the man forgetting to open the top. Such negligence causes the lamp to go out as soon as it has consumed the limited supply of air enclosed in it, and then of course, although the lamp is supposed to be in action, no signal is displayed, and serious mischief may result.

Another advantage is, that the oil-reservoir of these lamps drops through the inner shell of the lamp, and is kept cool by being exposed to wind and weather, while the flame is perfectly protected.

SILESIAN LINENS. See FLAX and LINEN.

SILEX. Quartz, or pure flint. See SILICA.

SILICA or **SILICIC ACID.** SiO^3. This substance exists nearly pure in rock-crystal, chalcedony, opal, agate, and many other minerals; and it is an important constituent of a very large class of minerals. See AGATE; OPAL; QUARTZ.

It may be obtained perfectly pure by precipitation from any of its combinations. Silicic acid forms a class of salts termed silicates, which are generally formed by fusing silicic acid with the bases. Those silicates in which the acid predominates are insoluble in water, and constitute the different varieties of glass. See GLASS.

Recent researches have shown that crystallised silica exists in nature under three distinct forms: (1) *Quartz*, crystallising in the hexagonal system, with sp. gr. 2·6; (2) *Tridymite*, crystallising in the same system, but with different parameters, and with sp. gr. 2·3; (3) *Asmanite*, belonging to the rhombic system, and having a sp. gr. of 2·24.

Some curious natural deposits of silica are found in nature. Way discovered at Farnham large deposits of silica, in the condition in which it is readily soluble in hot solutions of caustic potash, or soda. These beds are situated at the base of the chalk formations, between the Upper Greensand and the Gault Clay. Mr. Way proposed to employ those beds as a convenient source of silicate of lime for agricultural purposes. He found that a mixture of slaked lime with the powdered rock, when made into a thin paste and left for some weeks, is entirely converted into silicate of lime. The action is promoted by the presence of 2 or 3 per cent. of carbonate of soda; the latter appearing to act as the carrier between the silica and the lime. Similar deposits had been previously found by Sauvage in the Département des Ardennes.

Siliceous deposits are often formed from warm springs. In the Island of Terceira a deposit of this kind contains 77·05 of silicic acid. The hot springs of New Zealand deposit a crust containing 75 of silica; and some springs in the Azores leave precipitated a stratum containing 67·6 of silica. In the Steamboat Springs in California remarkable deposits of silica, associated with metallic sulphides, are in course of formation.

The Dinas sand, Glamorganshire, is remarkable. Some samples are actually pure silica, and most of it gives 91·95 of silicic acid: the sand of Penderyn, in the same county, giving 94·05 silica. A similar deposit is found near Llandudno, in North Wales. See STONE, ARTIFICIAL.

SILICATE PAINTS. Curious local deposits of almost pure silica have been discovered near Llandudno, in North Wales. The deposit lies in a basin, at a considerable level above the sea, and appears to form the bed of a small lake. The silica bed has a thickness of several feet, and overlies a deposit of greater thickness, but less purity. The following analysis has been made thereof:—Silica, 79 parts; water, 13; oxide of iron, 3; alumina, 4; magnesia, 1.

This material is unique, and possesses a wide range of usefulness in the arts and manufactures. It would be especially suited for producing crystal glass, and in the manufacture of porcelain, if the small percentage of oxide of iron were removed from it. Again, chemists report that this earth is a peculiar and interesting material, and is almost pure silica thoroughly calcined, reduced to such an impalpable powder as to be, without further treatment, fit to be employed in various ways.

The material, when excavated, is freely washed in water, which holds it in partial suspension, and is then allowed to dry, when it becomes brilliantly white, and is more finely divided than could be done by mechanical means. At present the use made thereof is in the production of paint. Before being so used the water is dried out, so that the base of the paint contains 92 per cent. of pure silica. For this purpose it is especially suitable, as it mixes freely with the pigments and oils, and is worked with the greatest ease. Moreover, it entirely resists the action of acid, and the effect of heat, and, when laid on, becomes extremely hard and polished on the surface; no small advantages.

The Silicate Paint Company (Fenwick Street, Liverpool), supply this useful paint. Its preservative influence, in shielding sensitive materials from the destructive action of heat and flame in conflagrations is insisted on, but surely a mere coating of silica cannot possess any extraordinary power in this respect.

The Silicate Paint Company also manufacture a water-proofing solution from this peculiar silica, which, when applied to the interior or exterior of houses, entirely excludes damp. The silica is conveyed into the pores of the brick, plaster, stone, or other material, and the action of the air causes it to petrify and return to its original condition. See STONE, ARTIFICIAL.

SILICATISATION. The process of impregnating bodies with silica.

SILICATES. Compounds of silicic acid (*silica, oxide of silicon* or *silicium*), with earthy, alkaline, or metallic bases. In mineralogical arrangements these have been divided into *anhydrous silicates*, which include, as Dana classifies them, the *augite* section, the *garnet* section, the *mica* section, the *felspar* section, and some others; and the *hydrous silicates*, which include the *talc* section, the *serpentine* section, the *chlorite* section, the *calamine* section, the *datholite*, and others.

SILICEOUS CEMENTS. An interesting paper on hydraulic cements was submitted to the Academy of Sciences by M. F. Kuhlmann, showing the advantage that may be derived from the combination of silicates with mortars and cements in general, and especially with those that are intended to resist the action of sea-water. It is well known that the first effect of water on cements is that of forming hydrates; after which a gradual contraction takes place, producing a degree of hardness, which increases in proportion as the contraction is slower, and there is more silex or alumina in the cement. Now, M. Kuhlmann has observed that if alumina or its silicate, or else magnesia, whether caustic or carbonated, be kneaded into a paste with a solution of silicate of potash or soda, the compounds resulting therefrom will bear a perfect resemblance to the natural silicates, such as felspar, talcose slate, magnesite, &c., and will, by repose and slow contraction, become hard and semi-transparent, resisting in a high degree the erosive effects of water. If slaked lime be added to the said compounds they acquire the properties of hydraulic cements. M. Vicat, junr., having shown that calcined magnesia added to a cement would resist the action of sulphate of magnesia, M. Kuhlmann endeavoured to turn this observation to account, by mixing calcined dolomites (which contain magnesia) with mortar, containing the alkaline silicates. This composition he found very advantageous, since most of the salts contained in sea-water must contribute towards the preservation of such cements. In fact, the chloride of magnesium, as well as the sulphate of magnesia, will be decomposed and form a layer of silicate of magnesia on the surface of the cement; in the same manner, the sulphate of lime must, being in contact with the silicate of potash or soda, form a silicate of lime; and all these silicates strongly resist the action of sea-water. As for sea-salt, which is a chloride of sodium, M. Kuhlmann proved that, in the proportion in which it exists in sea-water, it will slowly decompose the silicate of potash contained in the cement, and leave the silex free. The compositions proposed have therefore the singular property, not only of resisting the action of sea-water, but of actually becoming more insoluble the longer they are in contact with it. A cement composed of 30 parts of rich lime, 50 of sand, 15 of uncalcined clay, and 5 of powdered silicate of potash, is recommended by M. Kuhlmann as having all the requisite hydraulic properties, especially for cisterns intended for spring-water. In marine constructions care should be taken to add an excess of silicate to those portions of cement which are exposed to the immediate contact of the sea. See HYDRAULIC CEMENTS.

Ransome's artificial stone is prepared by cementing sand with soluble silica, or silicate of potash, and decomposing this salt with muriate of lime. See STONE, ARTIFICIAL.

SILICON, or **SILICIUM.** The base of silica or flint. It was first obtained by Berzelius in 1823. Silicon is obtained by heating the double fluoride of potassium and silicon with sufficient potassium to combine with the whole of the fluorine, and afterwards washing the mass with cold water, until no alkaline reaction is observable, then boiling with water to decompose any of the double fluoride which may not have been acted upon, and finally washing the silicon perfectly with hot water.

Silicon is a dark-brown powder, heavier than water, infusible before the blowpipe, non-volatile, increasing in density when considerably heated. Silicon exists in three distinct forms: amorphous, graphitoïdal, and diamond-like. Silicon, boron, and carbon, indeed, exhibit great similarity.

SILK MANUFACTURE. (*Fabrique de soie*, Fr.; *Seidenfabrik*, Ger.) This may be divided into two branches: 1. the production of raw silk; 2. its filature and preparation in the mill, for the purposes of the weaver. The threads, as spun by the silkworm, and wound up in its cocoon, are all twins, in consequence of the twin orifice in the lip of the insect through which they are projected. These two threads are laid parallel to each other, and are glued more or less evenly together by a kind of glossy varnish, which also envelopes them, constituting nearly 25 per cent. of their weight. Each ultimate filament measures about $\frac{1}{2000}$ of an inch in average fine silk, and the pair measures of course fully $\frac{1}{1000}$ of an inch. In the raw silk, as imported from Italy, France, China, &c., several of these twin filaments are slightly twisted and agglutinated to form one thread, called single.

The specific gravity of silk is 1·300, water being 1·000. It is by far the most tenacious or the strongest of all textile fibres, a thread of it of a certain diameter being nearly three times stronger than a thread of flax, and twice stronger than hemp. Some varieties of silk are perfectly white, but the general colour is a golden yellow.

The production of silk was unknown in Europe till the sixth century, when two monks, who brought some eggs of the silkworm from China or India to Constantinople, were encouraged to breed the insect, and cultivate its cocoons, by the Emperor Justinian. Several silk manufactures were in consequence established in Athens, Thebes, and Corinth, not only for rearing the worm upon mulberry-leaves, but for unwinding its cocoons, for twisting their filaments into stronger threads, and weaving these into robes. The Venetians having then and long afterwards intimate commercial relations with the Greek Empire, supplied the whole of western Europe with silk goods, and derived great riches from the trade.

About 1130, Roger II., king of Sicily, set up a silk manufacture at Palermo, and another in Calabria, conducted by artisans whom he had seized and carried off as prisoners of war in his expedition to the Holy Land. From these countries, the silk industry soon spread throughout Italy. It seems to have been introduced into Spain at a very early period, by the Moors, particularly in Murcia, Cordova, and Granada. The last town, indeed, possessed a flourishing silk trade when it was taken by Ferdinand in the 15th century. The French having been supplied with workmen from Milan, commenced, in 1521, the silk manufacture; but it was not till 1564 that they began successfully to produce the silk itself, when Traucat, a working gardener at Nismes, formed the first nursery of white mulberry-trees, and with such success, that in a few years he was enabled to propagate them over many of the southern provinces of France. Prior to this time, some French noblemen on their return from the conquest of Naples, had introduced a few silkworms with the mulberry into Dauphiny; but the business had not prospered in their hands. The mulberry-plantations were greatly encouraged by Henry IV.; and since then they have been the source of most beneficial employment to the French people. James I. was most solicitous to introduce the breeding of silkworms into England, and in a speech from the throne he earnestly recommended his subjects to plant mulberry-trees; but he totally failed in the project. This country does not seem well adapted for this species of husbandry, on account of the great prevalence of blighting east winds during the months of April and May, when the worms require a plentiful supply of mulberry-leaves. The manufacture of silk goods, however, made great progress during that king's peaceful and pompous reign. In 1629 it had become so considerable in London that the silk-throwsters of the city and suburbs were formed into a public corporation. So early as 1661 they employed 40,000 persons. The revocation of the Edict of Nantes, in 1685, contributed in a remarkable manner to the increase of the English silk trade, by the influx of a large colony of skilful French weavers, who settled in Spitalfields. The great silk-throwing mill mounted at Derby, in 1719, also served to promote the extension of this branch of manufacture; for soon afterwards, in the year 1730, the English silk goods bore a higher price in Italy than those made by the Italians, according to the testimony of Keysler.

The ordinary silkworm, called by entomologists *Bombyx mori*, is, like its kindred species, subject to four metamorphoses. The egg, fostered by the genial warmth of spring, sends forth a caterpillar, which, in its progressive enlargement, casts its skin either three or four times, according to the variety of the insect. Having acquired its full size in the course of 25 or 30 days, and ceasing to eat during the remainder of its life, it begins to discharge a viscid secretion, in the form of twin filaments, from tubes opening on the under lip, which harden in the air. These threads are coiled into an ovoïd nest round itself, called a cocoon, which serves as a defence against living enemies and changes of temperature. Here it soon changes into the chrysalis or nymph state, in which it lies swaddled, as it were, for about 15 or 20 days. Then it bursts its cerements, and comes forth furnished with appropriate wings, antennæ, and feet, for living in its new element, the atmosphere. The male and the female moths couple together at this time, and terminate their union by a speedy death, their whole existence being limited to two months. The cocoons are completely formed in the course of three or four days; the finest being reserved as seed-worms. From these cocoons, after an interval of 18 or 20 days, the moth makes its appearance, perforating its tomb by knocking with its head against one end of the cocoon, after softening it with saliva, and thus rendering the filaments more easily torn asunder by its claws. Such moths or aurelias are collected and placed upon a piece of soft cloth, where they couple and lay their eggs.

The eggs, or grains as they are usually termed, are enveloped in a liquid which causes them to adhere to the piece of cloth or paper on which the female lays them. From this glue they are readily freed, by dipping them in cold water, and wiping them dry. They are best preserved in the *ovum* state at a temperature of about 55° F. If the heat of spring advances rapidly in April, it must not be suffered to act on the eggs, otherwise it might hatch the caterpillars long before the mulberry has sent forth its leaves to nourish them. Another reason for keeping back their incubation is, that they may be hatched together in large broods, and not by small numbers in succession. The eggs are made up into small packets, of an ounce, or somewhat more, which in the south of France are generally attached to the girdles of the women during the day, and placed under their pillows at night. They are, of course, carefully examined from time to time. In large establishments, they are placed in an appropriate stove-room, where they are exposed to a temperature gradually increased till it reaches the 86th degree of Fahrenheit's scale, which temperature it must not exceed. Aided by this heat, nature completes her mysterious work of incubation in eight or ten days. The teeming eggs are now covered with a sheet of paper pierced with numerous holes, about $\frac{1}{12}$th of an inch in diameter. Through these apertures the new-hatched worms creep upwards instinctively, to get at the tender mulberry-leaves strewed over the paper.

The nursery where the worms are reared is called by the French a *magnanière;* it ought to be a well-aired chamber, free from damp, excess of cold or heat, rats and other vermin. It should be ventilated occasionally, to purify the atmosphere from the noisome emanations produced by the excrements of the caterpillars and the decayed leaves. The scaffolding of the wicker-work shelves should be substantial; and they should be from 15 to 18 inches apart. A separate small apartment should be allotted to the sickly worms. Immediately before each moulting, the appetite of the worms begins to flag; it ceases altogether at that period of cutaneous metamorphosis, but revives speedily after the skin is fairly cast, because the internal parts of the animal are thereby allowed freely to develope themselves. At the end of the second age, the worms are half an inch long; and should then be transferred from the small room in which they were first hatched, into the proper apartment where they are to be brought to maturity and set to spin their balls. On occasion of changing their abode, they must be well cleansed from the litter, laid upon beds of fresh leaves, and supplied with an abundance of food every six hours in succession. In shifting their bed, a piece of network being laid over the wicker-plates, and covered with leaves, the worms will creep up over them; when they may be transferred in a body upon the net. The litter, as well as the sickly worms, may thus be readily removed, without handling a single healthy one. After the third age, they may be fed with entire leaves; because they are now exceedingly voracious, and must not be subsequently stinted in their diet. The exposure of chloride of lime, spread thin upon plates, to the air of the *magnanière*, has been found useful in counteracting the tendency which sometimes appears of an epidemic disease among the silkworms, from the fœtid exhalations of the dead and dying,

When they have ceased to eat, either in the fourth or fifth age, according to the variety of the *bombyx*, and when they display the spinning instinct by crawling up among the twigs of heath, &c., they are not long in beginning to construct their cocoons, by throwing the thread in different directions, so as to form the floss, *filoselle*, or outer open network, which constitutes the *bourre* or silk for carding and spinning.

The cocoons destined for filature, must not be allowed to remain for many days with the worms alive with them; for should the chrysalis have leisure to grow mature or come out, the filaments at one end would be cut through, and thus lose almost all their value. It is therefore necessary to extinguish the life of the animal by heat, which is done either by exposing the cocoons for a few days to sunshine, by placing them in a hot oven, or in the steam of boiling water. A heat of 202° Fahr. is sufficient for effecting this purpose, and it may be best administered by plunging tin cases filled with the cocoons into water heated to that pitch.

80 pounds French (= 88 Engl.) of cocoons, are the average produce from one ounce of eggs, or 100 from an ounce and a quarter; but M. Folzer of Alsace obtained no less than 165 pounds. The silk obtained from a cocoon is from 750 to 1,150 feet long. The varnish by which the coils are glued slightly together, is soluble in warm water.

The silk husbandry, as it may be called, is completed in France within six weeks from the end of April, and thus affords the most rapid of agricultural returns, requiring merely the advance of a little capital for the purchase of the leaf. In buying up cocoons, and in the filature, indeed, capital may be often laid out to great advantage. The most hazardous period in the process of breeding the worms, is at the third and fourth moulting; for upon the sixth day of the third age, and the seventh day of the fourth, they in general eat nothing at all. On the first day of the fourth age, the worms proceeding from one ounce of eggs will, according to Bonafons, consume upon an average twenty-three pounds and a quarter of mulberry-leaves; on the first of the fifth age, they will consume forty-two pounds; on the sixth day of the same age, they acquire their maximum voracity, devouring no less than 223 pounds. From this date their appetite continually decreases, till on the tenth day of this age they consume only fifty-six pounds. The space which they occupy upon the wicker-tables, being at their birth only nine feet square, becomes eventually 239 feet. In general, the more food they consume the more silk will they produce.

A mulberry-tree is valued, in Provence, at from 6*d.* to 10*d.*; it is planted out of the nursery at four years of age; it is begun to be stripped in the fifth year, and affords an increasing crop of leaves till the twentieth. It yields from 1 cwt. to 30 cwts. of leaves, according to its magnitude and mode of cultivation. One ounce of silkworm eggs is worth in France about 2½ francs; it requires for its due development into cocoons about 15 cwts. of mulberry-leaves, which cost upon an average 3 francs per cwt. in a favourable season. One ounce of eggs is calculated, as I have said, to produce from 80 to 100 pounds of cocoons, of the value of 1 fr. 25 centimes per pound, or 125 francs in the whole. About 8 pounds of reeled raw silk, worth 18 francs a pound, are obtained from these 100 pounds of cocoons.

There are three denominations of raw silk: viz., organzine, *trame* (shute or tram), and floss. Organzine serves for the warp of the best silk stuffs, and is considerably twisted; tram is made usually from inferior silk, and is very slightly twisted, in order that it may spread more, and cover better in the weft; floss, or *bourre*, consists of the shorter broken silk, which is carded and spun like cotton. Organzine and trame may contain from 3 to 30 twin filaments of the worm; the former possesses a double twist, the component filaments being first twisted in one direction, and the compound thread in the opposite; the latter receives merely a slender single twist. Each twin filament gradually diminishes in thickness and strength, from the surface of the cocoon, where the animal begins its work in a state of vigour, to the centre, where it finishes it, in a state of debility and exhaustion; because it can receive no food from the moment of its beginning to spin by spouting forth its silky substance. The winder is attentive to this progressive attenuation, and introduces the commencement of some cocoons to compensate for the termination of others. The quality of raw silk depends, therefore, very much upon the skill and care bestowed upon its filature.

The quality of the raw silk is determined by first winding off 400 ells of it, equal to 475 meters, round a drum one ell in circumference, and then weighing that length. The weight is expressed in grains, 24 of which constitute one denier; 24 deniers constitute one ounce; and 16 ounces make one pound, *poids de marc*. This is the Lyons rule for valuing silk. The weight of a thread of raw silk 400 ells long, is two grains and a half, when five twin filaments have been reeled and associated together.

Raw silk is so absorbent of moisture, that it may be increased ten per cent. in weight by this means. This property has led to falsifications; which are detected by enclosing weighed portions of the suspected silk in a wire-cloth cage, and exposing it to a stove heat of about 78° Fahr. for twenty-four hours, with a current of air. The loss of weight which it thereby undergoes, demonstrates the amount of the fraud. There is an office in Lyons called the *Condition*, where this assay is made, and by the report of which the silk is bought and sold. The law of France requires, that all the silk tried by the *Condition* must be worked up into fabrics in that country. It has been lately noticed that a still more serious falsification of silks has been made in France. The silks are treated with astringent vegetable decoctions, and then with salts of iron—the cyanides and, in some cases, iodides being also used. It is stated that the weight of the silk can be, by this process, more than doubled. At the same time it is considerably deteriorated in quality; and if a flame is applied to it, it burns like tinder. It is found also, in some cases, to be spontaneously combustible.

Switzerland.—There are silk-stuff factories in the canton of Bâle: but the trade of this town lies in the manufacture of silk-ribbons. In this and the neighbouring canton of Bâle-Champagne there are about 4,000 looms, which give employment to 16,000 workmen, as weavers, dyers, &c. Manual labour is extremely cheap, enabling the manufacturer to sell at a very low rate. The greater number of the manufacturers of this canton employ their own capital, and have not to surmount those difficulties and disadvantages inseparable from the employment of borrowed principal. The chief articles of manufacture are plain taffeta, ribbons, plain satin, and figured ribbons: in all these articles, Bâle maintains an incontestable superiority.

The silk trade in Switzerland has grown and prospered without the aid of protective duties, and it is a remarkable fact that the difficulties occasioned by the high prohibitive customs, instead of being prejudicial, have been of advantage, by increasing the active genius and emulation of the manufacturers, and inducing them to seek more distant and more favourable outlets for their goods. The morality, activity, and commercial knowledge of the Swiss may be considered the basis of their success.

The production of silk is conducted on the most important scale in the Lombardo-Venetian States; next in order of importance comes the Tyrol: the same business is also carried on in the military frontier, Görz and Gradiska, and also in Istria and Trieste, in Dalmatia and south of Hungary. Trials have likewise been made in Lower Austria, Bohemia, and Carniola.

The cocoons are prepared at the reeling establishment into raw silk. From the result of inquiries, it would appear that Lombardy comprises 3,060 reeling establishments. The entire production amounts to 2,512,000 Vienna lbs.; and since 12 lbs. of cocoons yield 1 lb. of raw silk, there are required for this aggregate of raw silk 300,400 cwts. of cocoons. The quantity of cocoons required in excess of the quantity produced, an excess of nearly 50,000 cwts., is covered by the production of the Venetian provinces, chiefly by that of Verona.

Within the province of Venice, the reeling establishments are also numerous. The nearest approximation in reference to this matter is obtained by taking the extent of the production at one-half of that in Lombardy. The remainder of the cocoons produced in the province undergo further preparation in Lombardy, and partly in the Tyrol also; whilst a portion of those obtained in Görz and Gradiska, as well as in Istria, are prepared in Venetian reeling establishments.

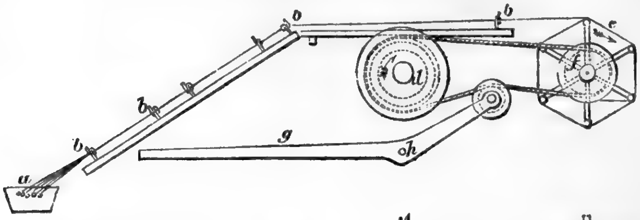
The whole production of raw silk obtained in the Austrian monarchy is about 4,108,700 lbs. The number of working hands employed in the reeling establishments is not less than 160,000. Besides the products already enumerated, about 900 cwts. of cocoons are annually imported into Lombardy, principally from Switzerland and the neighbouring Italian States, and are prepared in the Lombardy reeling establishments.

The raw silk undergoes further preparation in the throwing mills; but the whole mass of the production is not thus worked up within the monarchy, for the exports of raw silk are found considerably to exceed the imports.

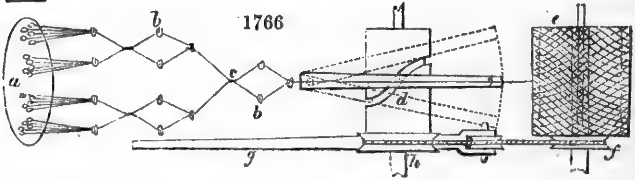
There are in the Tyrol above 55 throwing mills, with 125,047 spindles; 85,583 of which latter are for spinning, and 39,464 for twisting. In these mills 500 men and 1,200 women and children are employed. The production there, including that of the smaller throwing mills, which give occupation to 500 workmen, amounts to 220,400 Vienna lbs. of thrown silk, for which 231,400 Vienna lbs. of raw silk have to be worked up.

The mechanism of the silk filature, as improved in France, is very ingenious. *Figs.* 1765 and 1766 exhibit it in plan and longitudinal view. *a* is an oblong copper basin containing water heated by a stove or by steam. It is usually divided by transverse partitions into several compartments, containing 20 cocoons, of which there are five in one group, as shown in the figure. *b*, *b*, are wires with hooks or eylets at their ends, through which the filaments run, apart, and are kept from ravelling. *c*, *c*, the points where the filaments cross and rub each other, on purpose to clean their surfaces. *d* is a spiral groove, working upon a pin-point, to give the traverse motion alternately to right and left, whereby the thread is spread evenly over the surface of the reel *e*. *f*, *f*, are the pulleys, which by means of cords transmit the rotatory movement of the cylinder *d* to the reel *e*. *g* is a friction lever or tumbler, for lightening or slackening the endless cord, in the act of starting or stopping the winding operation. Every apartment of a large filature contains usually a series of such reels as the above, all driven by one prime mover; each of which, however, may, by means of the tumbler-lever, be stopped at pleasure. The reeler is careful to remove any slight adhesions by the application of a brush in the progress of her work.

1765



1766



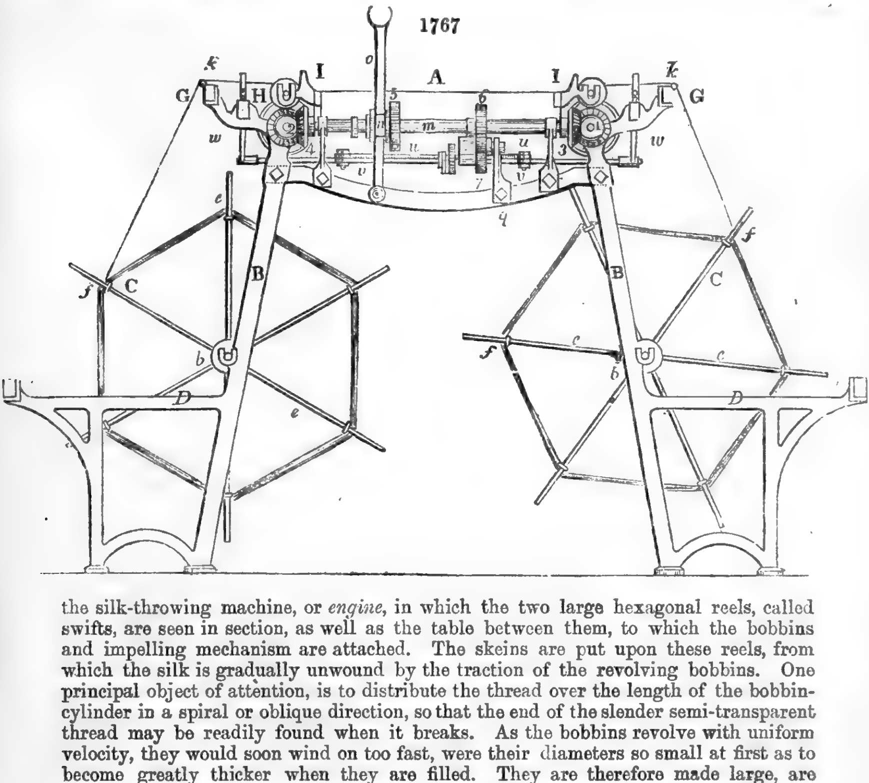
The expense of reeling the excellent Cevennes silk is only 3 francs and 50 centimes per Alais pound; from 4 to 5 cocoons going to one thread. That pound is 92 hundredths of our avoirdupois pound. In Italy, the cost of reeling silk is much higher, being 7 Italian livres per pound, when 3 to 4 cocoons go to the formation of one thread; and 6 livres when there are from 4 to 5 cocoons. The first of these raw silks will have a *titre* of 20 to 24 deniers; the last, of 24 to 28. If 5 to 6 cocoons go to one thread, the titre will be from 26 to 32 deniers, according to the quality of the cocoons. The Italian livre is worth 7½*d.* English. The woman employed at the kettle receives one livre and five sous per day; and the girl who turns the reel gets thirteen sous a day; both receiving board and lodging in addition. In June, July, and August, they work 16 hours a day, and then they wind a *rubo* or ten pounds weight of cocoons, which yield from 1-5th to 1-6th of silk, when the quality is good. The whole expenses amount to from 6 or 7 livres upon every ten pounds of cocoons; which is about 2*s.* 8*d.* per English pound of raw silk.

The raw silk, as imported into this country in hanks from the filatures, requires to be regularly wound upon bobbins, doubled, twisted, and reeled in our silk-mills. These processes are called *throwing* silk, and their proprietors are called silk *throwsters;* terms probably derived from the appearance of swinging or tossing which the silk-threads exhibit during their rapid movements among the machinery of the mills.

It was in Manchester that throwing-mills received the greatest improvement upon the ancient Italian plan, which had been originally introduced into this country by Sir Thomas Lombe, and erected at Derby. That improvement is chiefly due to the eminent factory engineers, Messrs. Fairbairn and Lillie, who transferred to silk the elegant mechanism of the throstle, so well known in the cotton trade. Still, throughout the silk districts of France the throwing-mills are generally small, not many of them turning off more than 1,000 pounds of organzine per annum, and not involving 5,000*l.* of capital. The average price of throwing organzine in that country, where the throwster is not answerable for loss, is 7 francs; of throwing trame, from 4 fr. to 5 fr. (per kilogramme?) Where the throwster is accountable for loss, the price is from 10 fr. to 11 fr. for organzine, and from 6 to 7 for trame. In Italy, throwing adds 3*s.* 9*d.* to the price of raw silk, upon an average. It seems probable, from the perfection and speed of the silk-throwing machinery in this country, as about to be described, that the cost of converting a pound of raw silk either into organzine or trame must be considerably under any of the above sums.

The first process to which the silk is subjected, is winding the skeins, as imported, off upon bobbins. The mechanism which effects this winding off and on, is technically called the *engine*, or swift. The bobbins to which the silk is transferred, are wooden cylinders, of such thickness as may not injure the silk by sudden flexure, and which may also receive a great length of thread without having their diameter materially increased, or their surface velocity changed. *Fig.* 1767 is an end view of the silk-throwing machine, or *engine*, in which the two large hexagonal reels, called swifts, are seen in section, as well as the table between them, to which the bobbins and impelling mechanism are attached. The skeins are put upon these reels, from which the silk is gradually unwound by the traction of the revolving bobbins. One principal object of attention, is to distribute the thread over the length of the bobbin-cylinder in a spiral or oblique direction, so that the end of the slender semi-transparent thread may be readily found when it breaks. As the bobbins revolve with uniform velocity, they would soon wind on too fast, were their diameters so small at first as to become greatly thicker when they are filled. They are therefore made large, are not covered thick, but are frequently changed. The motion is communicated to that end of the engine shown in the figure.

1767

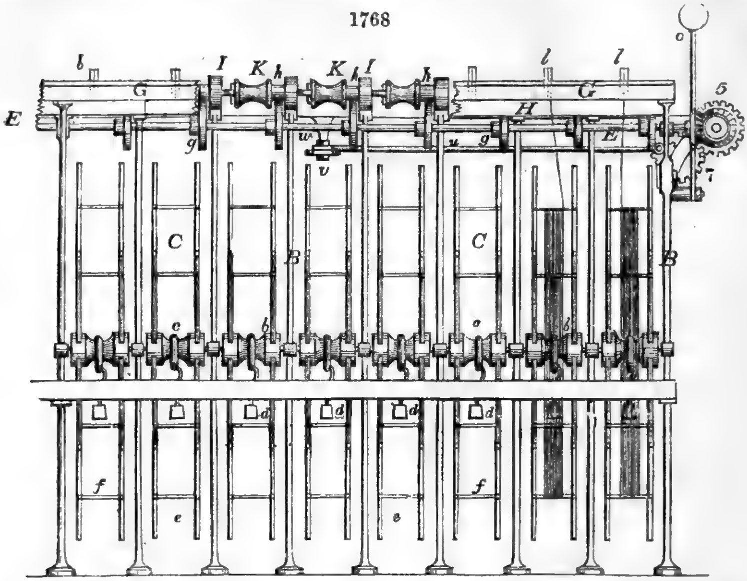


The wooden table A, shown here in cross section, is sometimes of great length, extending 20 feet, or more, according to the size of the apartment. Upon this the skeins are laid out. It is supported by the two strong slanting legs B, B, to which the bearings of the light reels C are made fast. These reels are called *swifts*, apparently by the same etymological casuistry as *lucus a non lucendo*, for they turn with reluctant and irregular slowness; yet they do their work much quicker than any of the old apparatus, and in this respect may deserve their name. At every eighth or tenth leg there is a projecting horizontal piece D, which carries at its end another horizontal bar *a*, called the knee-rail, at right angles to the former. This protects the slender reels or swifts from the knees of the operatives.

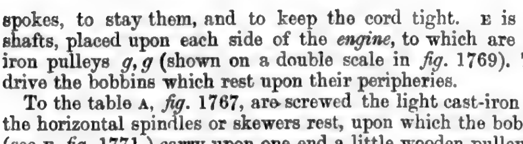
These swifts have a strong wooden shaft *b*, with an iron axis passing longitudinally through it, round which they revolve, in brass bearings fixed near to the middle of the legs B. Upon the middle of the shaft *b*, a loose ring is hung, shown under *c*, in *fig.* 1768, to which a light weight *d*, is suspended, for imparting friction to the reel, and thus preventing it from turning round, unless it be drawn with a gentle force, such as the traction of the thread in the act of winding upon the bobbin.

Fig. 1768 is a front view of the engine. B, B, are the legs, placed at their appropriate distances (scale 1½ inch to the foot); C, C, are the swifts. By comparing *figs.* 1768 and 1769, the structure of the swifts will be fully understood. From the wooden shaft *b*, six slender wooden (or iron) spokes *e*, *e*, proceed, at equal angles to each other; which are bound together by a cord *f*, near their free ends, upon the transverse line *f*, of which cord, the silk thread is wound in a hexagonal form; due tension being given to the circumferential cords, by sliding them out from the centre. Slender wooden rods are set between each pair of spokes, to stay them, and to keep the cord tight. E is one of the two horizontal shafts, placed upon each side of the *engine*, to which are affixed a number of light iron pulleys *g*, *g* (shown on a double scale in *fig.* 1769). These serve, by friction, to drive the bobbins which rest upon their peripheries.

1768

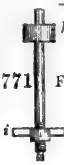


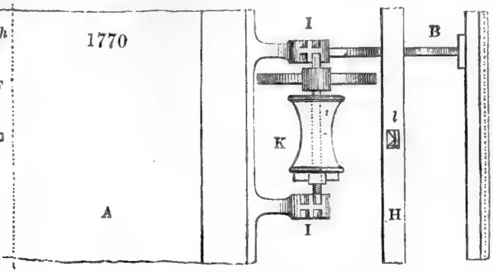
1769



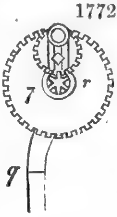
To the table A, *fig.* 1767, are screwed the light cast-iron slot bearings, I, I, wherein the horizontal spindles or skewers rest, upon which the bobbins revolve. The spindles (see F, *fig.* 1771,) carry upon one end a little wooden pulley *h*, whereby they press and revolve upon the larger driving pulleys *g*, of the shaft E. These pulleys are called *stars* by our workmen. The other ends of the spindles, or skewers, are cut into screws, for attaching the swivel-nuts *i* (*fig.* 1771), by which the bobbins K, K (*fig.* 1768), are made fast to their respective spindles. Besides the slots, above described, in which the spindles rest when their friction pulleys *h*, are in contact with the moving stars *g*, there is another set of slots in the bearings, into which the ends of the spindles may be occasionally laid, so as to be above the line of contact of the rubbing periphery of the star *g*, in case the thread of any bobbin breaks. Whenever the girl has mended the thread, she replaces the bobbin-spindle in its deeper slot-bearings, thereby bringing its pulley once more into contact with the star, and causing it to revolve.

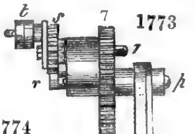
G (*fig.* 1768) is a long ruler or bar of wood, which is supported upon every eighth or twelfth leg B, B. (The figure being, for convenience of the page, contracted in length, shows it at every sixth leg.) To the edge of that bar the smooth glass-rods *k*, are made fast, over which the threads glide from the swifts, in their way to the bobbins. H (*fig.* 1770) is the guide-bar, which has a slow traverse or seesaw motion, sliding in slots at the top of the legs B, where they support the bars G. Upon the guide-bar H, the guide-pieces *l*, *l*, are made fast. These consist of two narrow, thin, upright plates of iron, placed endwise together, their contiguous edges being smooth, parallel, and capable of approximation to any degree by a screw, so as to increase or diminish at pleasure the ordinary width of the vertical slit that separates them. Through this slit the silk thread must pass, and, if rough or knotty, will be either cleaned or broken; in the latter case, it is neatly mended by the attendant girl.

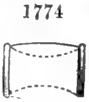

1771


1770

The motions of the various parts of the *engine* are given as follows:—Upon the end of the machine, represented in *fig.* 1767, there are attached to the shafts E (*fig.* 1768), the bevel-wheels 1 and 2, which are set in motion by the bevel-wheels 3 and 4, respectively. These latter wheels are fixed upon the shaft *m*, *fig.* 1767; *m* is moved by the main steam-shaft which runs parallel to it, and at the same height through the length of the *engine* apartment, so as to drive the whole range of the machines. 5 is a loose wheel or pulley upon the shaft *m*, working in gear with a wheel upon the steam-shaft, and which may be connected by the clutch *n*, through the hand-lever or gearing-rod *o* (*figs.* 1767 and 1768), when the engine is to be set at work. 6 is a spur-wheel upon the shaft *m*, by which the stud-wheel 7, is driven, in order to give the traverse motion to the guide-bar H. This wheel is represented, with its appendages, in double size, *figs.* 1772 and 1773, with its boss upon a stud *p*, secured to the bracket *q*. In an eccentric hole of the same boss, another stud *r*, revolves, upon which the little wheel *s*, is fixed. This wheel *s* is in gear with a pinion cut upon the end of the fixed stud *p*; and upon it is screwed the little crank *t*, whose collar is connected by two rods *u* (*figs.* 1767 and 1768), to a cross-piece *v*, which unites the two arms *w*, that are fixed upon the guide-bar H, on both sides of the machine. By the revolution of wheel 7, the wheel *s* will cause the pinion of the fixed stud *p* to turn round. If that wheel bear to the pinion the proportion of 4 to 1, then the wheel *s* will make, at each revolution of the wheel 7, one-fourth of a revolution; whereby the crank *t* will also rotate through one-fourth of a turn, so as to be brought nearer to the centre of the stud, and to draw the guide-bar so much less to one side of its mean position. At the next revolution of wheel 7, the crank *t* will move through another quadrant, and come still nearer to the central position, drawing the guide-bars still less aside, and therefore causing the bobbins to wind on more thread in their middle than towards their ends. The contrary effect would ensue, were the guide-bars moved by a single or simple crank. After four revolutions of the wheel 7, the crank *t* will stand once more as shown in *fig.* 1774, having moved the bar H through the whole extent of its traverse. The bobbins, when filled, have the appearance represented in *fig.* 1774; the thread having been laid on them all the time in diagonal lines, so as never to coincide with each other.


1772


1773


1774

Doubling is the next operation of the silk-throwster. In this process, the threads of two or three of the bobbins, filled as above, are wound together in contact upon a single bobbin. An ingenious device is here employed to stop the winding-on the moment that one of these parallel threads happens to break. Instead of the swifts or reels, a creel is here mounted for receiving the bobbins from the former machine, two or three being placed in one line over each other, according as the threads are to be doubled or trebled. Though this machine is in many respects like the *engine*, it has some additional parts, whereby the bobbins are set at rest, as above mentioned, when one of the doubling-threads gets broken.

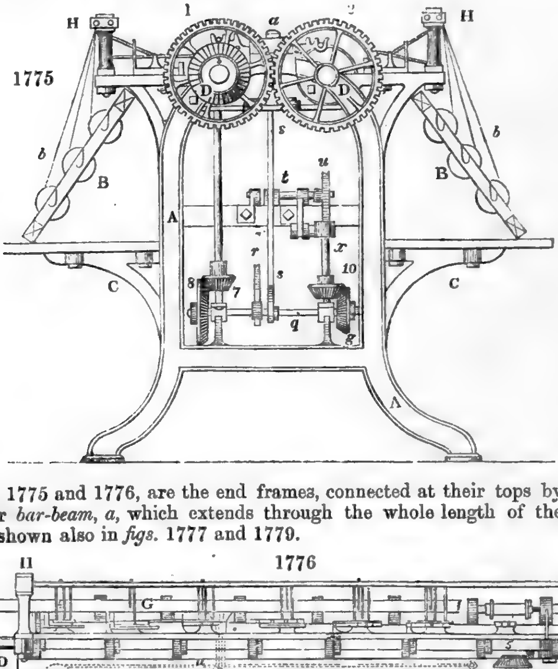
Fig. 1775 is an end view, from which it will be perceived that the machine is, like the preceding, a double one, with two working sides.

Fig. 1776 is a front view of a considerable portion of the machine.

Fig. 1777 shows part of a cross section, to explain minutely the mode of winding upon a single bobbin.

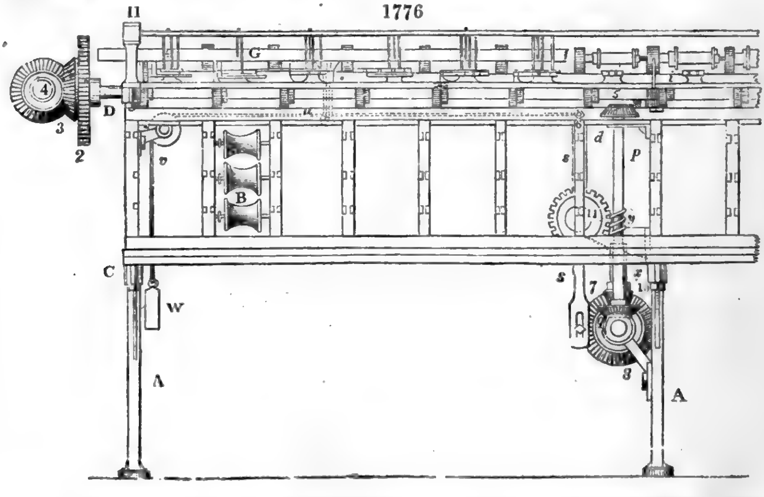
Fig. 1779 is the plan of the parts shown in *fig.* 1777; these two figures being drawn to double the scale of *figs.* 1775 and 1776.

1775



A, A, *figs.* 1775 and 1776, are the end frames, connected at their tops by a wooden stretcher, or *bar-beam*, *a*, which extends through the whole length of the machine; this bar is shown also in *figs.* 1777 and 1779.

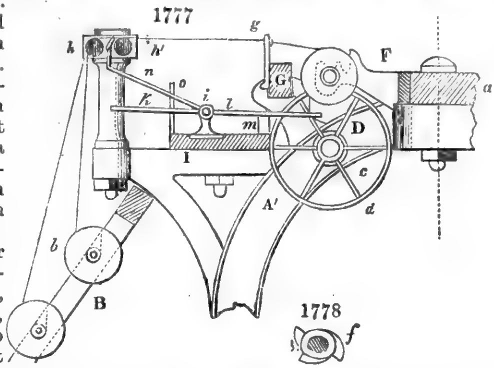
1776



B, B, are the creels upon each side of the machine, or bobbin-bearers, resting upon wooden beams or boards, made fast to the arms or brackets C, about the middle of the frames A.

D, D, are two horizontal iron shafts, which pervade the whole machine, and carry a series of light moveable pulleys, called *stars, c, c* (*figs.* 1777, 1779), which serve to drive the bobbins E, whose fixed pulleys rest upon their peripheries, and are therefore turned simply by friction. These bobbins are screwed by swivel-nuts, *e, e,* upon spindles, as in the silk-engine. Besides the small friction-pulley, or boss, *d,* seen best in *fig.* 1779, by which they rest upon the star-pulleys *c, c,* a little ratchet-wheel, *f,* is attached to the other end of each bobbin. This is also shown by itself at *f,* in *fig.* 1778.

1777

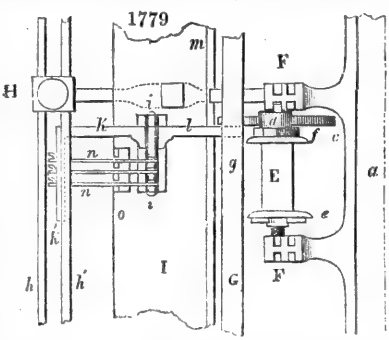


1778

The spindles, with their bobbins, revolve in two slot-bearings, F, F, *fig.* 1779, screwed to the bar-beam *a,* which is supported by two or three intermediate upright frames, such as A'. The slot-bearings F have also a second slot, in which the spindle with the bobbin is laid at rest, out of contact of the *star*-wheel, while its broken thread is being mended. G is the guide-bar (to which the cleaner slit-pieces, *g, g,* are attached), for making the thread traverse to the right and the left, for its proper distribution over the surface of the bobbin. The guide-bar of the doubling-machine is moved with a slower traverse than in the engine; otherwise, in consequence of the different obliquities of the paths, the single threads would be readily broken. *h, h,* is a pair of smooth rods of iron or brass, placed parallel to each of the two sides of the machine, and made fast to the standards H, H, which are screwed to brackets projecting from the frames A, A'. Over these rods the silk threads glide, in their passage to the guide-wires *g, g,* and the bobbins E.

I, I, is the *lever-board* upon each side of the machine, upon which the slight brass bearings or fulcrums *i, i,* one for each bobbin in the creel, are made fast. This board bears the *balance-lever k, l,* with the *fallers n, n, n,* which act as dexterous fingers, and stop the bobbin from winding-on the instant a thread may chance to break. The levers *k, l,* swing upon a fine wire axis, which passes through their props *i, i,* their arms being shaped rectangularly, as shown at *k, k'* (*fig.* 1779). The arm *l* being heavier than the arm *k,* naturally rests upon the ridge-bar *m,* of the lever-board I. *n, n, n,* are three wires, resting at one of their ends upon the axis of the fulcrum *i, i,* and having each of their other hooked ends suspended by one of the silk threads, as it passes over the front steel rod *h,* and under *h'.* These faller-wires, or stop-fingers, are guided truly in their up-and-down motions with the thread, by a cleaner-plat *o,* having a vertical slit in its middle. Hence, whenever any thread happens to break, in its way to a winding-on bobbin E, the wire *n,* which hung by its eyelet end to that thread, as it passed through between the steel rods in the line of *h, h',* falls upon the lighter arm of the balance-lever *k, l,* weighs down that arm *k,* consequently jerks up the arm *l,* which pitches its tip or end into one of the three notches of the racket or catch-wheel *f* (*figs.* 1778 and 1779), fixed to the end of the bobbin. Thus its motion is instantaneously arrested, till the girl has had leisure to mend the thread, when she again hangs up the faller-wire *n,* and restores the lever *k, l,* to its horizontal position. If, meanwhile, she took occasion to remove the winding-bobbin out of the sunk slot-bearing, where pulley *d* touches the *star*-wheel *c,* into the right-hand upper slot of repose, she must now shift it into its slot of rotation.

1779



The motions are given to the doubling-machine in a very simple way. Upon the end of the frame, represented in *fig.* 1775, the shafts bear two spur-wheels, 1 and 2, which work into each other. To the wheel 1 is attached the bevel-wheel 3, driven by another bevel-weeel 4 (*fig.* 1776), fixed to a shaft that extends the whole length of the apartment, and serves, therefore, to drive a whole range of machines. The wheel 4 may be put in gear with the shaft, by a clutch- and gear-handle, as in the silk-*engine*, and thereby it drives two shafts, by the one transmitting its movement to the other.

The traverse-motion of the guide-bar G is effected as follows:—Upon one of the shafts D, there is a bevel-wheel 5, driving the bevel-wheel 6, upon the top of the upright shaft *p* (*fig.* 1776, to the right of the middle); whence the motion is transmitted to the horizontal shaft *q* below, by means of the bevel-wheels 7 and 8. Upon this shaft *q*, there is a heart-wheel *r*, working against a roller which is fixed to the end of the lever *s*, whose fulcrum is at *t*, *fig.* 1775. The other end of the lever *s*, is connected by two rods (shown by dotted lines in *fig.* 1776) to a brass piece which joins the arms *u* (*fig.* 1776), of the guide-bars G. To the same cross-piece a cord is attached, which goes over a roller *v*, and suspends a weight W, by means of which the lever *s*, is pressed into contact with the heart-wheel *r*. The fulcrum *t*, of the lever *s*, is a shaft which is turned somewhat excentric, and has a very slow rotatory motion. Thus the guide-bar, after each traverse, necessarily winds the silk in variable lines to the side of the preceding threads.

The motion is given to this shaft in the following way:—Upon the horizontal shaft *q*, there is a bevel-wheel *g* (*figs.* 1775 and 1776), which drives the wheel 10 upon the shaft *x*; on whose upper end, the worm *y* works on the wheel 11, made fast to the said excentric shaft *t*; round which the lever *s*, swings or oscillates, causing the guide-bars to traverse.

The Spinning Silk-mill.—The machine which twists the silk threads, either in their single or doubled state, is called the spinning-mill. When the raw singles are first twisted in one direction. next doubled, and then twisted together in the opposite direction, an exceedingly wiry, compact thread, is produced, called ***organzine***. In the spinning-mill, either the singles or the doubled silk, while being unwound from one set of bobbins, and wound upon another set, is subjected to a regular twisting operation; in which process the thread is conducted as usual through guides, and coiled diagonally upon the bobbins by a proper mechanism.

1780

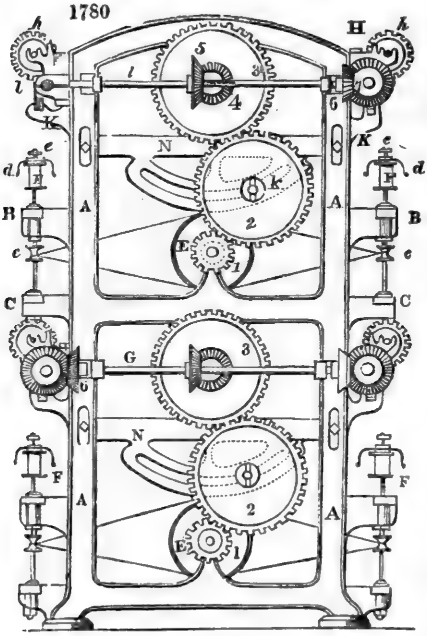


Fig. 1780 exhibits an end-view of the spinning-mill; in which four working lines are shown; two tiers upon each side, one above the other. Some spinning-mills have three working tiers upon each side; but as the highest tier must be reached by a ladder or platform, this construction is considered by many to be injudicious.

Fig. 1781 is a front view, where, as in the former figure, the two working lines are shown.

Fig. 1782, is a cross section of a part of the machine, to illustrate the construction and play of the working parts; *figs.* 1788, 1789, are other views of *fig.* 1782.

Fig. 1784, shows a single part of the machine, by which the bobbins are made to revolve.

Figs. 1783 and 1785, show a different mode of giving the traverse to the guide-bars, than that represented in *fig.* 1782.

Figs. 1786 and 1787, show the shape of the full bobbins, produced by the action of these two different traverse motions.

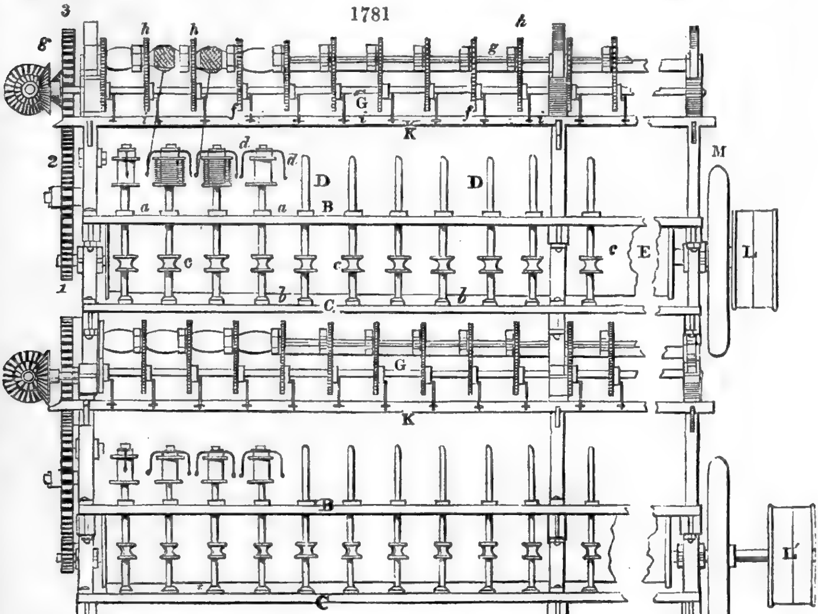
The upper part of the machine being exactly the same as the under part, it will be sufficient to explain the construction and operation of one of them.

A, A, are the end upright frames or standards, between which are two or three intermediate standards, according to the length of the machine. They are all connected at their sides by beams B and C, which extend the whole length of the machines.

D, D, are the spindles, whose top bearings *a*, *a*, are made fast to the beams B, and their bottoms turn in hard brass steps, fixed to the bar C. These two bars together are called by the workmen the spindle-box. The standards A, A, are bound with cross-bars N, N.

c, *c*, are the wharves or whorls, turned by a band from the horizontal tin cylinder in the lines of E, *fig.* 1781, lying in the middle lines between the two parallel rows of spindles D, D. F, F, are the bobbins containing the untwisted double silk, which are simply pressed down upon the taper end of the spindles. *d*, *d*, are little flyers, or forked wings of wire, attached to washers of wood, which revolve loose upon the tops of the said bobbins F, and round the spindles. One of the wings is sometimes bent upwards, to serve as a guide to the silk, as shown by dotted lines in *fig.* 1782. *e*, *e*, are pieces of wood pressed upon the tops of the spindles, to prevent the flyers from starting off by the centrifugal force. G are horizontal shafts bearing a number of little spur-wheels *f*, *f*. H are slot-bearings, similar to those of the doubling-machine, which are fixed to the end and middle frames. In these slots, the light square cast-iron shafts or spindles *g*, *fig.* 1784, are laid, on whose end the spur-wheel *h* is cast; and when the shaft *g* lies in the front slot of its bearing, it is in gear with the wheel *f*, upon the shaft G; but when it is laid in the back slot, it is out of gear, and at rest. See F, F, *fig.* 1780.

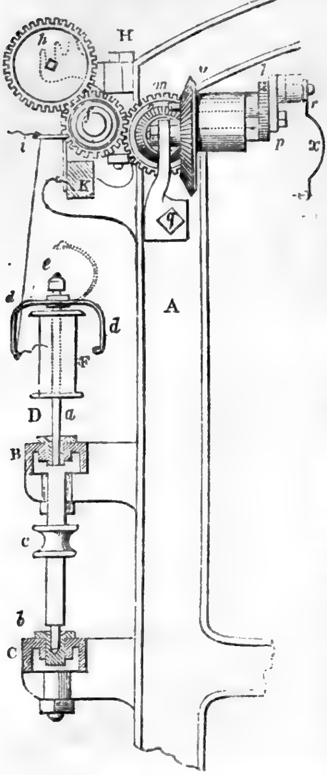
1781



Upon these little cast-iron shafts or spindles *g*, *fig.* 1784, the bobbins or blocks I, are thrust, for receiving by winding-on the twisted or spun silk. These blocks are made of a large diameter, in order that the silk fibres may not be too much bent; and they are but slightly filled at each successive charge, lest, by increasing their diameter too much, they should produce too rapid an increase in the rate of winding, with proportional diminution in the twist, and risk of stretching or tearing the silk. They are therefore the more frequently changed. K, K, are the guide-bars, with the guides *i*, *i*, through which the silk passes, being drawn by the revolving bobbins I, and delivered or laid on by the flyers *d*, *d*, from the rotatory twisting-bobbins F. The operation of the machine is therefore simple, and the motions are given to the parts in a manner equally so.

Upon the shaft of the tin cylinder or drum, exterior to the frame, the usual fast and loose pulleys or riggers, L, L′, are mounted, for driving the whole machine. These riggers are often called steam-pulleys by the workmen, from their being connected by bands with the steam-driven shaft of the factory. In order to allow the riggers upon the shafts of the upper and the under drums to be driven from the same pulley upon the main shaft, the axis of the under drum is prolonged at L, L′, and supported at its end, directly from the floor, by an upright bearing. Upon the shafts of the tin cylinders there is also a fly-wheel, M, to equalise the motion. Upon the other ends of these shafts, namely, at the end of the spinning mill, represented in *fig.* 1782, the pinions 1, are fixed, which drive the wheels 3, by means of the intermediate or carrier-wheel, 2, called also the plate-wheel, from its being hollowed somewhat like a trencher. 1 is called the change pinion, because it is changed for another of a different size and different number of teeth, when a change in the velocity of wheels 2 and 3 is to be made. To allow a greater or smaller pinion to be applied at 1, the wheel 2 is mounted upon a stud *k*, which is moveable in a slot concentric with the axis of the wheel 3. This slot is a branch from the cross-bar N. The smaller the change-pinion is, the nearer will the stud *k* approach to the vertical line joining the centres of wheels 1 and 3; and the more slowly will the plate-wheel 2 be driven. To the spur-wheel 3, a bevel-wheel 4, is fixed, with which the other also revolves loose upon a stud. The bevel-wheel 5, upon the shaft *l*, is driven by the bevel-wheel 4; and it communicates motion, by the bevel-wheels 6 and 7, to each of the horizontal shafts G, G, extending along the upper and under tiers of the machine. At the left-hand side of the top part of *fig.* 1781, the two wheels 6 and 7 are omitted, on purpose to show the bearings of the shaft G, as also the slot-bearings for carrying the shafts or skewers of the bobbins.

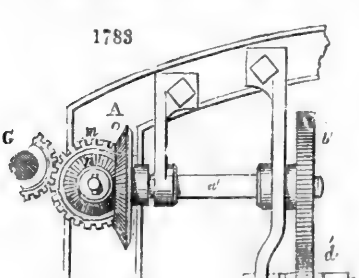
1782



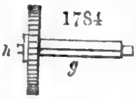
If it be desired to communicate twist in the opposite direction to that which would be given by the actual arrangement of the wheels, it is necessary merely to transpose the carrier-wheel 2, from its present position on the right hand of pinion 1, to the left of it, and to drive the tin cylinder by a crossed or close strap, instead of a straight or open one.

The traverse motion of the guide is given here in a similar way to that of the engine (*fig.* 1766). Near one of the middle or cross-frames of the machine (see *fig.* 1782), the wheel *f*, in gear with a spur-wheel *h*, upon one of the block-shafts, drives also a spur-wheel *m*, that revolves upon a stud, to which wheel is fixed a bevel-wheel *n*, in gear with the bevel-wheel *o*. To wheel *o*, the same mechanism is attached as was described under *figs.* 1780 and 1781, and which is here marked with the same letters.

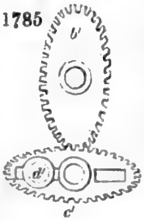
1783



1784

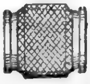


1785

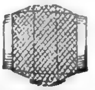


To the crank-knob *r*, *fig.* 1782, a rod, *x*, is attached, which moves or traverses the guide-bar belonging to that part of the machine: to each machine one such apparatus is fitted. In *figs.* 1783 and 1785, another mode of traversing the guide-bar is shown, which is generally used for the coarser qualities of silk. Near to one of the middle frames, one of the wheels *f*, in gear with the spur-wheel *m*, and the bevel-wheel *n*, both revolving on one stud, gives motion also to the wheel *o*, fixed upon a shaft *a′*, at whose other end the elliptical wheel b' is fixed, which drives a second elliptical wheel c', in such a way that the larger diameter of the one plays in gear with the smaller diameter of the other; the teeth being so cut as to take into each other in all positions. The crank-piece d' is screwed upon the face of the wheel c', at such a distance from its centre as may be necessary to give the desired length of traverse motion to the guide-bar, for laying the silk spirally upon the blocks. The purpose of the elliptical wheel is to modify the simple crank-motion, which would wind on more silk at the ends of the bobbins than in their middle, and to effect an equality of winding-on over the whole surface of the blocks. In *fig.* 1785, the elliptical wheels are shown in front, to illustrate their mode of operating upon each other.

1786



1787



1788

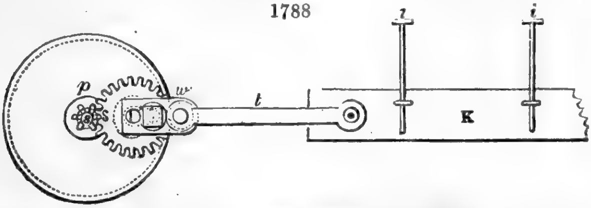
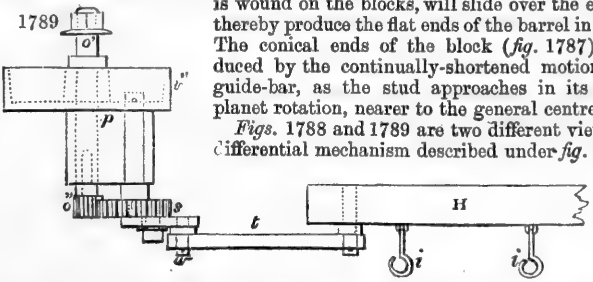


Fig. 1786, is a block filled by the motion of the excentric, *fig.* 1782; and *fig.* 1787, is a block filled by the elliptical mechanism. As the length of the motions of the bar in the latter construction remains the same during the whole operation, the silk, as it is wound on the blocks, will slide over the edges, and thereby produce the flat ends of the barrel in *fig.* 1786. The conical ends of the block (*fig.* 1787) are produced by the continually-shortened motions of the guide-bar, as the stud approaches in its sun-and-planet rotation, nearer to the general centre.

Figs. 1788 and 1789 are two different views of the differential mechanism described under *fig.* 1782.

1789



The bent wire *x*, *fig.* 1782, is called the guide-iron. It is attached at one end to the pivot of the sun-and-planet wheel-work *t*, *s*, *o*, and at the other to the guide-bar *f*, *f*, *fig.* 1781. The silk threads pass through the guides, as already explained. By the motion communicated to the guide-bar (*guider*), the diamond-pattern is produced, as shown in *fig.* 1786.

The Silk Automatic Reel.

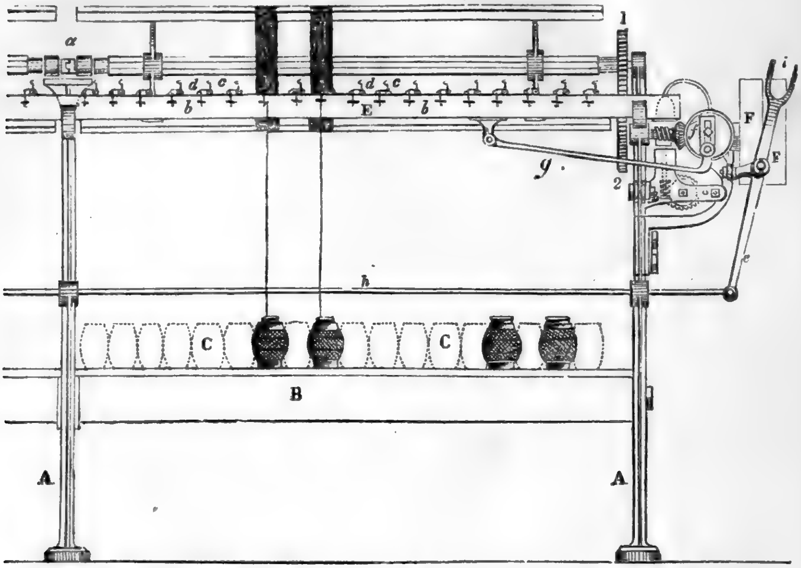
In this machine, the silk is unwound from the blocks of the throwing-mill, and formed into hanks for the market. The blocks being of a large size, would be productive of much friction, if made to revolve upon skewers thrust through them, and would cause frequent breakage of the silk. They are, therefore, set with their axes upright upon a board, and the silk is drawn from their surface, just as the weft is from a cop in the shuttle. On this account the previous winding-on must be executed in a very regular manner, and preferably as represented in *fig.* 1786.

Fig. 1790, is a front view of the reel; little more than one-half of it being shown.

Fig. 1791, is an end view. Here the steam-pulleys are omitted, for fear of obstructing the view of the more essential parts. A, A, are the two end framings, connected by mahogany stretchers, which form the table B, for receiving the bobbins C, C, which are sometimes weighted at top with a lump of lead to prevent their tumbling. D is the reel, consisting of four long laths of wood, which are fixed upon iron frames, attached to an octagonal wooden shaft. The arm which sustains one of these laths is capable of being bent inwards by loosening a tightening hook, so as to permit the hanks, when finished, to be taken off, as in every common reel.

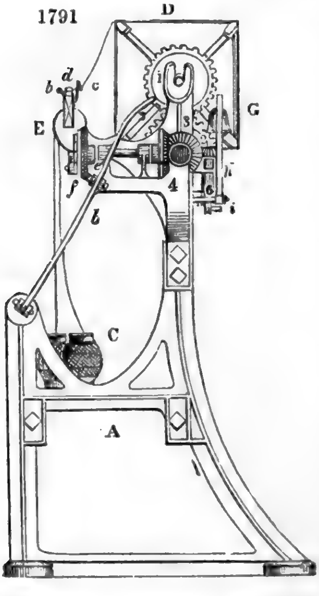
The machine consists of two equal parts coupled together at *a*, to facilitate the removal of the silk from either half of the reel; the attendant first lifting the one part and then the other. E, is the guide-bar, which by a traverse motion causes the silk to be wound on in a cross direction. *b* and *c* are the wire-guides, and *d* are little levers lying upon the cloth-covered guide-bar E. The silk in its way from the block to the reel, passes under these levers, by which it is cleaned from loose fibres.

1790



On the other end of the shaft of the reel, the spur-wheel 1 is fixed, which derives motion from wheel 2, attached to the shaft of the steam-pulley F. Upon the same shaft there is a bevel-wheel 3, which impels the wheel 4 upon the shaft *e*; to whose end a plate is attached, to which the crank *f* is screwed, in such a way as to give the proper length of traverse motion to the guide-bar E, connected to that crank or excentric stud by the jointed rod *g*. Upon the shaft of the steam-pulleys F, there is a worm or endless screw, to the left of *f*, *fig.* 1790, which works in a wheel 5, attached to the short upright shaft *h* (*fig.* 1791). At the end of *h* there is another worm, which works in a wheel, 6; on whose circumference there is a stud, *i*, which strikes once at every revolution against an arm attached to a bell, seen to the left, G; thus announcing to the reel-tenter that a measured length of silk has been wound upon her reel. *e*, is a rod or handle, by which the fork *l*, with the strap, may be moved upon the fast or loose pulley, so as to set on or arrest the motion at pleasure.

1791



Throwsters submit their silk to scouring and steaming processes. They soak the hanks, as imported, in lukewarm soap-water in a tub; but the bobbins of the twisted single silk from the spinning mill are enclosed within a wooden chest and exposed to the opening action of steam for about ten minutes. They are then immersed in a cistern of warm water, from which they are transferred to the doubling-frame.

The wages of the work-people in the silk-throwing mills of Italy are about one-half of their wages in Manchester; but this difference is much more than counterbalanced by the superior machinery of our mills.

There is a peculiar kind of silk called *marabout*, containing generally three threads, made from the white Novi raw silk. From its whiteness, it takes the most lively and delicate colours without the discharge of its gum. After being made into tram by the single twist upon the spinning mill, it is reeled into hanks, and sent to the dyer without further preparation. After being dyed, the throwster re-winds and re-twists it upon the spinning mill, in order to give it the whip-cord hardness which constitutes the peculiar feature of marabout. The cost of the raw Novi silk is 19*s.* 6*d.* a pound; of throwing it into tram, 2*s.* 6*d.*; of dyeing, 2*s.*; of re-winding and re-twisting, after it has been dyed, about 5*s.*; of waste, 2*s.*, or 10 per cent.: the total of which sum is 31*s.*; being the price of one pound of marabout in 1832.

As nearly as can be ascertained, the following is a correct statement of the present condition of our silk-manufacture (1874):—

The number of silk factories in England and Wales are: Spinning, 227; weaving, 390; spinning and weaving, 39; others, 36: total, 692. Scotland: spinning and weaving, 4. Total in the United Kingdom, 696 factories.

The number of spindles in the United Kingdom being: Spinning, 940,143; doubling, 190,298.

The number of power-looms, 12,378.

The motive horse-power of the machinery employed being: Steam, 7,604; water, 985.

Total number of persons employed, 48,124.

At present the United Kingdom draws its supply of the raw material for manufacture principally from the East Indies; and France, Italy, Turkey, and China, also supply a considerable amount. About 20 years since, the annual imports for home consumption amounted to 4,734,755 lbs.

In 1857, the quantity of 12,077,931 lbs. of silk in its several conditions of raw, waste, and thrown, was imported into this country.

The following represents our *Import* trade in silk for the year 1873:—

			£
Knubs, or husks, and waste	31,815 cwts.	value	460,128
Raw	6,445,213 lbs.		6,758,138
Thrown	108,794 ,,		195,025

Silk Manufactures.

		£
Of countries out of Europe	value	284,889
,, countries in Europe		4,752,692
,, velvet, plain or figured		691,597
,, ribbons		1,705,420
,, ,, other kinds		621,494
,, plush, used for hats		27,731
,, manufactures of silk, or of silk mixed with other materials, unenumerated		1,981,555

Exports of Silk in 1873.

	Value £
Thrown, Twist or Yarn	1,667,545

Manufactures.

	Yards	
Broad stuffs of silk or satin	1,696,605	331,293
Handkerchiefs, scarfs, and shawls	—	245,326
Ribbons of all kinds	—	232,933
Lace	—	231,435
Unenumerated	—	550,522
Of Silk and other materials:—		
Broad stuffs	1,287,107	196,973
Other kinds	—	90,118

Silk imported in 1874.

	lbs.	Value
From China	2,656,764	£1,996,203
,, British India	690,871	568,998
,, Egypt	149,086	130,631
,, Other countries	2,446,717	3,321,814
Total	5,943,438	5,017,646

Silk manufactures imported in 1874 from countries in Europe.

			£
Broad stuffs	From France . .	of the value of	4,940,309
	,, Belgium .	,,	2,271,902
	,, Other countries	,,	116,863
	Total . . .		7,329,074
Ribbons, silk and satin .	From France . .	of the value of	1,829,039
	,, Other countries	,,	246,843
	Total . . .		2,075,882
Ribbons, other kinds . .	From Belgium .	of the value of	200,130
	,, Other countries	,,	239,619
	Total . . .		439,749

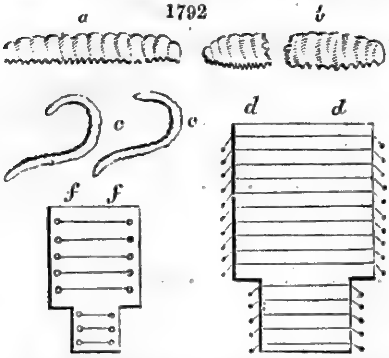
Of countries out of Europe of the value of £237,735.

Silk manufacture, Exports in 1874.

Wholly of silk	Yards	Value
Broad stuffs of silk or satin	2,311,345	£458,422
Thrown, twist or yarn	...	1,029,682
Handkerchiefs, scarfs and shawls . . .	...	387,509
Ribbons of all sorts	...	207,256
Of silk and other materials	...	362,442

SILKWORM GUT, for angling, is made as follows :—Select a number of the best and largest silkworms, just when they are beginning to spin; which is known by their refusing to eat, and having a fine silk thread hanging from their mouths. Immerse them in strong vinegar, and cover them closely for twelve hours, if the weather be warm, but two or three hours longer, if it be cool. When taken out, and pulled asunder, two transparent guts will be observed, of a yellow-green colour, as thick as a small straw, bent double. The rest of the entrails resembles boiled spinage, and therefore can occasion no mistake as to the silk-gut. If this be soft, or break upon stretching it, it is a proof that the worm has not been long enough under the influence of the vinegar. When the gut is fit to draw out, the one end of it is to be dipped into the vinegar, and the other end is to be stretched gently to the proper length. When thus drawn out, it must be kept extended on a thin piece of board, by putting its extremities into slits in the end of the wood, or fastening them to pins, and then exposed in the sun to dry. Thus genuine silk-gut is made in Spain. From the manner in which it is dried, the ends are always more or less compressed or attenuated. In *fig.* 1792, *a* is the silkworm ; *b*, the worm torn asunder ; *c, c*, the guts ; *d, d*, a board slit at the ends, with the gut to dry ; *f, f*, boards with wooden pegs, for the same purpose.

1792



SILVER (*Argent*, Fr. ; *Silber*, Ger.) was formerly called a *perfect* metal, because heat alone revived its oxide, and because it could pass unchanged through trials by fire, which apparently destroyed most other metals. The distinctions, perfect, imperfect, and noble, are now rejected.

When pure and polished, silver is the brightest of the metals. Its specific gravity in the ingot is 10·47 ; but, when condensed under the hammer or in the coining-press, it becomes 10·6. It melts at a bright red heat, at a temperature estimated by some as equal to 1873° Fahr. It is exceedingly malleable and ductile, affording leaves not more than $\frac{1}{100000}$ of an inch thick, and wire far finer than a human hair.

By Sickingen's experiments, its tenacity is, to that of gold and platinum, as the number 19, 15, and 26¼ ; so that it has an intermediate strength between these two metals. Pure atmospheric air does not affect silver, but that of houses impregnated with sulphuretted hydrogen soon tarnishes it with a film of brown sulphide. It is distinguished chemically from gold and platinum by its ready solubility in nitric acid, and from almost all other metals, by its saline solutions affording a curdy precipitate with a most minute quantity of sea-salt or any soluble chloride.

The atomic weight of silver is 108; its chemical symbol is Ag (*argentum*).

Silver occurs in nature under many forms:—

1. *Native silver* possesses most of the above properties; yet, on account of its being more or less alloyed with other metals, it differs a little in malleability, lustre, density, &c. It sometimes occurs crystallised in octahedrons, in cubes, and cubo-octahedrons. At other times it is found in dendritic shapes, or arborescences, resulting from minute crystals implanted upon each other. But more usually it presents itself in small grains without determinable form, or in amorphous masses of various magnitude.

The *gangues* (mineral matrices) of native silver are so numerous, that it may be said to occur in all kinds of rock. At one time it appears as if filtered into their fissures, at another as having vegetated on their surface, and at a third, as if impasted in their substance. Such varieties are met with principally in the mines of Peru.

The native metal is found in almost all the silver mines now worked; but especially in those of Kongsberg in Norway, in carbonate and fluoride of calcium, &c.; at Schlangenberg in Siberia, in sulphate of baryta; at Allémont, in a ferruginous clay, &c. The mines of Chili and Peru have yielded large quantities of native silver.

The metals most usually associated with silver in the native alloy, are gold, copper, arsenic, and iron. At Andreasberg and Guadalcanal it has been found alloyed with about five per cent. of arsenic. The auriferous native silver is the rarest.

2. *Antimonial silver, or Dyscrasite.*—This rare ore is destitute of malleability, and very brittle; spec. grav. 9·5. It melts before the blowpipe, and affords white fumes of oxide of antimony: being readily distinguished from arsenical iron and arsenical cobalt by its lamellar fracture. It consists of from 76 to 84 per cent. of silver, and from 24 to 16 of antimony.

3. *Argentite, Sulphide of silver or Silver glance.*—This is an opaque substance, of a dark-grey or leaden hue; slightly malleable, and easily cut with a knife, when it betrays a metallic lustre. The silver is easily separated by the blowpipe. It consists of 13 of sulphur to 89 of silver, by experiment; 13 to 87 are the theoretic proportions. Its specific gravity is 6·9. It occurs crystallised in cubes, and is found in the mines of Freiberg in Saxony, Joachimsthal in Bohemia, Schemnitz in Hungary, and Mexico.

4. *Pyrargyrite, Red Silver ore, Ruby Blende, or Antimoniated sulphide of silver,* is an ore remarkable for its lustre, colour, and the variety of its forms. It is friable, easily scraped by the knife, and affords a powder of a lively crimson-red. Its colour in mass is brilliant red, dark red, or even metallic reddish-black. It crystallises in a variety of hexagonal forms. Its constituents are: silver from 56 to 62; antimony from 20 to 24; sulphur from 16 to 18. It is found in almost all silver mines; but principally in those of Freiberg, Andreasberg, and Guadalcanal.

5. *Proustite, Light Red Silver ore, or Arsenical sulphide of silver,* is a similar but rarer mineral, in which arsenic takes the place of antimony.

6. *Stephanite, or Black sulphide of silver,* is a blackish, brittle mineral, affording globules of silver at the blowpipe. It is found at Allémont and at Freiberg; but more abundantly in the silver mines of Peru and Mexico. The Spaniards call it *negrillo*.

7. *Polybasite* is a sulphide of silver and copper, generally with antimony and arsenic. It occurs in Mexico, Chili, Nevada, and Idaho.

8. *Sternbergite* is a rare sulphide of silver and iron.

9. *Chloride of silver, or Horn silver.*—In consequence of its semi-transparent aspect, its yellowish or greenish colour, and such softness that it may be cut with the nail, this ore has been compared to horn, and may be easily recognised. It melts at the flame of a candle, and may be reduced when heated along with iron or black-flux. It is occasionally crystallised in forms belonging to the cubic system; but occurs chiefly in irregular forms, sometimes covering the native silver with a thick crust, as in Peru and Mexico. Its density is only 4·74. It is found in considerable quantities at North Dolcoath in Cornwall.

Chloride of silver sometimes contains 60 or 70 per cent. of clay; and is then called 'butter-milk ore' by the German miners.

10. *Bromide of silver* or *Bromyrite*, and *Iodide of silver* or *Iodyrite*, occur in the mines of Chili and Mexico; whilst a mineral called *Embolite*, which is a chloro-bromide of silver, is found rather abundantly in some of the mines of Chili.

11. *Carbonate of silver, or Selbite,* is a mineral of doubtful occurrence.

Large quantities of silver are annually obtained in this country, and in the lead-producing districts of Europe, by the treatment of argentiferous galena; but the New

Continent, which produces for the most part ores containing but a small proportion of lead, is estimated to furnish twelve times more silver than the Old. See Lead.

Silver has been produced in the following countries:—

Norway.—The mines of Kongsberg were discovered in 1623, and they have been worked, almost continuously, up to the present time, their average annual produce being about 18,000 lbs. troy.

Hungary, *Transylvania*, and the *Banat*, are stated to produce about 92,000 lbs. of silver annually.

Saxony and Bohemia.—The mines near Freiberg are the most important.

The *Mines of the Hartz* produce about 28,000 lbs. troy of silver annually; while those of the *Alps* produce small quantities.

France has no silver mines of importance.

In *Spain*, the mines of Guadalcanal and Cazalla have been highly productive. The total produce of the Spanish silver mines, in 20 years, was 8,200,000 Spanish ounces.

In *North America*, the mines of *Mexico* are the most ancient, and the silver lodes the most remarkable. The vein called the Veta Madre, of Guanaxuato, was often 200 feet in width, and that of Zacatecas is sometimes 75 feet wide. Humboldt stated the production of silver in Mexico, in 1789, to have been 7,314,344 lbs. troy. There are about sixteen silver mines producing silver ore at the present time in Mexico; the ores varying from 55 ounces to 81 ounces of silver to the ton. The Real del Monte Company produced annually silver to the value of three millions and a half of dollars.

Nevada.—The discovery of silver in this region dates only from 1859; but the production of silver and gold has been immense, often rising to nearly 300,000 tons of ore per annum; sometimes yielding silver to the value of 150 dollars per ton, and seldom of less value than 28 dollars. There are numerous other districts, which space will not allow us to mention. See 'The Mining and Metallurgy of Gold and Silver,' by J. Arthur Phillips, for full accounts of the North American silver mines.

South America.—The silver mines are confined to the Republics of Peru, Bolivia, and Chili. The mines of Cerro de Pasco are the most celebrated in Peru, the principal ores being known as *pacos*; these are ferruginous earths, containing varying amounts of silver. These mines were discovered in 1630, and are still being worked, upon a small scale. The production of silver, in Peru, has been estimated at 299,000 lbs. troy.

Bolivia.—The mines of Potosi, which once formed a portion of the viceroyalty of Buenos Ayres, are now included in this republic. Thirty-two veins have been worked in this historical mine, which was discovered in 1545, with great profit, and numerous smaller ones, with more or less advantage. In the province of Potosi, according to Whitney, the United States Geologist, there were, when he visited the district, 1,800 abandoned mines, and only 26 at work; in other parts, there were 2,365 mines abandoned, and only 40 at work.

Chili.—The most important silver mines of Chili are those in the neighbourhood of Copiapo. Chlorides of silver are the most abundant ores, but there are also arsenides and sulphides, the ore containing from 100 to 250 ounces of silver to the ton. Chili appears to have produced in seven years 1,750,000 lbs. of silver.

New Granada.—The Santa Anna mines, in the province of Mariquita, have been long celebrated. They produced 1,266,455 ounces of silver between 1852 and 1864. Since that time, the production has been limited.

Mexican Amalgamation Process.—The following description of the extraction and treatment of silver ores in Mexico is derived from a paper published by Mr. J. A. Phillips, who for some years acted as manager for the firm of John Taylor and Sons. His excellent description may be applied to the amalgamation process, as carried out in other places.

We may previously state some of the peculiar features observable in the working of the mines of Mexico, confining our attention to the mines of Guanaxuato, Zacatecas (including Fresnillo), and Real del Monte. The mines of Guanaxuato are situated upon one vein of great length and width. It should be understood that this vein, like all mineral veins, is not productive of silver ore throughout its whole extent, but the ore occurs in branches and bunches, leaving intermediate spaces of dead or unproductive ground; and, as an ordinary mine-level seldom exceeds 6 feet in width, it is clear that a level like this would not explore a vein of such dimensions as that of Guanaxuato, while the expense of cross-cutting, as miners term it, would require more capital than the owners of the mine were willing to risk, or able, in many instances, to spare. Hence, there sprang up in Guanaxuato a system of working well adapted to the circumstances noticed, and being based upon the principle that the hope of reward acts as a stimulus to exertion, was attended with the best effects, and led to the discovery of some of the richest deposits of ore.

This system is called that of the *buscones* or 'seekers,' who are the working miners. These men, at their own risk, work in the mines under certain restrictions; and following up such indications as may appear to them favourable, oftentimes meet with a valuable course of ore, but frequently work for months, earning scarcely enough for bare subsistence. While thus employed the *buscon* receives half the produce of the ore he breaks; and it may be readily conceived that if he should fall in with a rich deposit, his gains should be very large: thus, instances have been known where a man has obtained, in this way, 1,000 or 1,500 dollars in a month.

The owners of the mine, however, have the option of taking away such a discovery from the hands of the miner, after a short notice, and working it on their own account, or, as it is termed, *hacienda account*, when they pay the miners a dollar per day each, without any share of the ore. To do this, however, the mine must be rich, and as it is, a very large portion of the ore in Guanaxuato is raised by the *buscones*, who divide the produce equally with the owners.

The ore, being broken and separated as much as possible from the rocky parts underground, is tied up in the *botas* of bullocks' hides, which are drawn to the surface by the *malacates*, in the same manner as the water. In some of the Guanaxuato mines, labourers are employed to take the ore to the surface, and these will carry on their backs from 2 to 3 cwts., and perform several journeys in a day from the bottom of a mine 400 or 500 yards in depth. At the mine of Mellado there is a very excellent double tramroad, on an inclined plane of timber, upon which the ore is drawn up in waggons to a height of 200 varas from the bottom of the mine, where the diagonal joins the perpendicular shaft at about the same depth from the surface: each carriage will contain 160 arrobas of 25 lbs. each. The power applied is that of a malacate working underground; and here at 200 yards from the surface, and shut out from the light of day, one is surprised to behold a storehouse and stabling, with all the necessary appurtenances for thirty-six horses, employed in moving the machine above mentioned, nine horses working at a time.

Having brought the ore to the surface, it is conveyed to the mine-yard, and placed in separate heaps, under the eye of the *buscon* or miner, who prepares it for sale. At a stated time the auctioneer appears, accompanied by a clerk; he walks round to the heaps of ore in succession, and sells them in the following manner:—

Standing before the heap of ore to which he invites attention, those who come to purchase step forward and whisper into his ear the price they severally offer. When all have done, he declares aloud the name of the highest bidder, and the price, which are entered in a book by the clerk; and the same process is followed throughout until all the ore is sold.

The practice in the Real del Monte differs from both the others, but assimilates a little towards the Guanaxuato system, inasmuch as the miner has a share of the ore, called *partido*. This partido system has prevailed from a very early period, and has led to many broils and disturbances with the miners.

The method of extracting the silver from the ore, at the establishments maintained for that purpose, called '*haciendas de beneficio*,' or '*haciendas de Plata*,' of which there are many of great extent in the country, is thus carried forward. The Haciendas Nueva in Fresnillo, of Sauceda in Zacatecas, of Barrera in Guanaxuato, and of Regla at Real del Monte, are the principal establishments of this kind at present in use. That in Fresnillo is the largest used for amalgamation only, the outer walls being 492 varas in length by 412 varas in width. It was erected at a cost of 300,000 dollars, and is very complete in all its arrangements.

The Hacienda de Regla combines very extensive smelting works with those for amalgamation.

The ore being placed in heaps in the yard is broken by hammers into pieces of moderate size, and carefully picked; the richer parts being set aside for smelting, and the poorer for amalgamation.

In the smelting process, the ore after being crushed, is mixed with slag or remains from former smeltings, litharge or oxide of lead, and a little iron ore and lime. These are put into the furnace with charcoal, and the silver is brought down with the lead; the two metals being afterwards separated in refining furnaces. The German high furnace is usually employed, although the Castilian furnace described in the article on LEAD, would probably be found preferable.

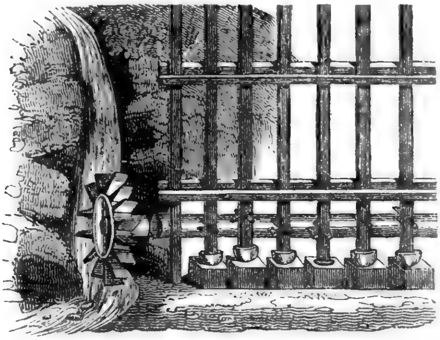
It is estimated that about an eighth part of the silver produced in Mexico is obtained by smelting; but as only the richest ores are subjected to this process, on account of the expense, which is from 15*l.* to 20*l.* per ton, except in a district like Zimapan, where lead ore is abundant, the proportion which the quantity of ore smelted bears when compared with that reduced by amalgamation must be very small indeed.

The process of amalgamation, to which attention is now more particularly directed, depends upon the great affinity of quicksilver for silver. In order, however, to make this known property available, certain operations are requisite, to reduce the silver contained in the ore to such a state that the quicksilver will readily combine with it.

After the breaking and dressing by hand, the ore is crushed, either by crushing-rollers or more generally by stamps, called in Mexico, *molinos*. The stamps are similar in principle to those used in the tin mines of Cornwall, but not so powerful, and are worked either by water-power or by mules. As the ore is crushed, it falls through small holes of about the size of a pea, perforated in strong hides stretched in a slope on either side of the machine placed over a pit which receives the fine ore, from whence it is conveyed to the *arrastres* or grinding mills.

These stamping mills are sometimes driven by a small breast water-wheel, of five feet diameter and one foot broad. *Fig.* 1793 will give a sufficient idea of their construction. The long horizontal shaft, fixed on the axis of the wheel, is furnished with 5 or 6 rams placed at different situations round the shaft, so as to act in succession on the projecting teeth of the upright rods or pestles. Each of these weighs 200 lbs., and works in a corresponding oblong mortar of stone or wood.

1793



The arrastre, or '*tahona*,' as it is called in the northern districts, is exceedingly simple, but for so rude a machine is very effective. Baron Humboldt, in alluding to it, says that he never saw ore so finely pulverised as he saw it in Mexico. In Guanaxuato, where there is much gold in the ore, this is particularly observable.

The arrastre consists, in the first place, of a strong wooden post moving on a spindle in a beam above it, and resting on an iron pivot beneath, turning in an iron socket on the top of a small post of hard wood which rises about a foot above the ground in the centre of the arrastre. See Ore Dressing.

These arrastres are usually arranged in rows in a large gallery or shed, as will be seen by reference to *fig.* 1794, which represents the gallery of the Hacienda of Salgado.

A machine has been introduced at Real del Monte which has superseded the old Mexican arrastres. This machine is similar in principle to some of the grinding mills of this country, and to the *trapiche* of Peru. It consists of two large circular edge stones faced with iron, and moving over iron bottoms, the ore being crushed and ground with water between the two metal-surfaces. The machine is turned by twelve mules in the twenty-four hours, four mules working at a time, and the quantity ground to a fine slime is sixty quintals, or about ten times the quantity ground by a common arrastre; and there is reason to believe that the quantity might be doubled by the use of water- or steam-power, as the number of revolutions would be increased.

The ore being brought into a finely-divided state, is allowed to run out of the arrastre into shallow tanks or reservoirs, where it remains exposed to the sun until a larger portion of the water has evaporated, when it has the appearance of thick mud; and in this state the process is proceeded with.

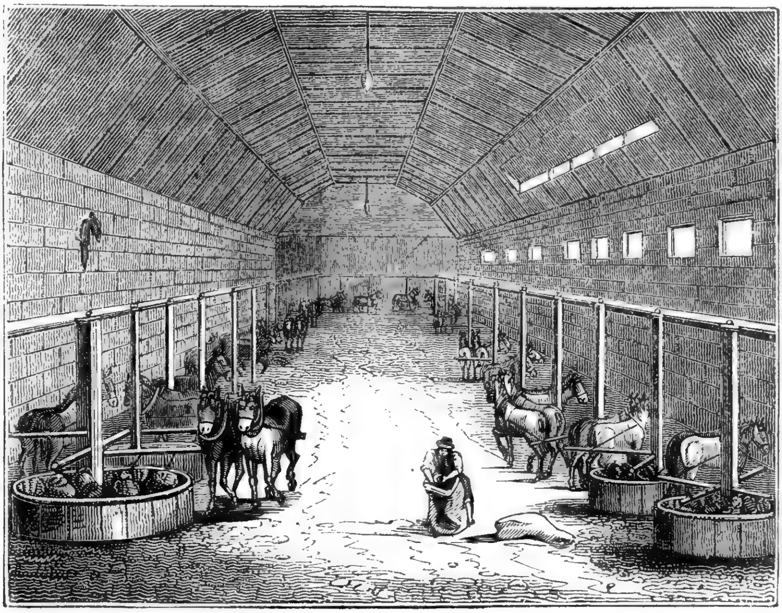
The *lama* as it is called, or slime, is now laid out on the *patio*, or amalgamation-floor (which is in some places boarded, and in others paved with flat stones), in large masses called *tortas*, 40 to 50 feet in diameter and about a foot thick, consisting frequently of 60 or 70 tons of ore; and so extensive are the floors that a large number of these tortas are seen in progress at the same time. Thus, at the Hacienda de Regla, the patio, which is boarded and carefully caulked, to render it water-tight, is capable of containing ten of these tortas, of about 60 tons each and 50 feet in diameter. The Hacienda de Barrera in Guanaxuato will hold eighteen tortas of 70 to 75 tons each. The Hacienda Sauceda at Zacatecas will contain twenty-four tortas of 60 tons each; and the patio floor of the Hacienda Nueva at Fresnillo is still larger, being 180 varas in length by as many in width, and capable of containing sixty-four tortas of 70 tons each!

Having laid out the masses of ore in the patio, the operations necessary to produce the chemical changes commence. The first ingredient introduced is salt, which is put into the torta in the proportion of 50 lbs. to every ton of ore (but varying in different districts), and a number of mules are made to tread it, so that it may become dissolved in the water, and intimately blended with the mass. On the following day another ingredient is introduced, called in Mexico *magistral*. It is common copper pyrites, or sulphide of copper and iron, pulverised and calcined, which converts it into a sulphate. About 25 lbs. of this magistral are added for every ton of ore in the torta, and the mules are again put in, and tread the mass for several hours. Chemical action now commences: the salt, magistral and metallic sulphurets are decomposed, and new combinations are in progress. Quicksilver is then introduced, being spread over the torta in very small particles, which is effected by passing it through a coarse cloth. The quantity required is six times the estimated weight of the silver contained in the ore, or 3 lbs. for every marc of 8 ozs.

The quicksilver being spread over the surface, the mules are once more put in, and tread the whole until it is well mixed. This treading is called the *repaso*, and is repeated every other day, or less often, according to the judgment of the *azoguero* or superintendent, until the operation is completed.

But it is in the progress of the operation that the skill of the azoguero is most required, because he must attend to certain signs or appearances which present themselves to him, and upon which depends the success of his work, whether as it regards the produce of silver or the economy of quicksilver and other materials and time. For this purpose he has a small quantity of the torta put on one side, upon which he operates before adding materials to the torta itself; this is called a *guia*, or guide.

1794



In order to ascertain how the chemical action in the torta proceeds, he collects a small quantity of the slime and washes it in a small bowl, and by the signs presented by the quicksilver and amalgam he, from his practical knowledge of the subject, is able to judge as to the state of the torta; whether it requires more magistral or quicksilver; or whether it has had too much magistral, in which case it is hot, and a little lime must be put in to decompose the excess of chloride of copper. This simple plan is termed the *tentadura*, by which in fact the azoguero is guided throughout the amalgamation process.

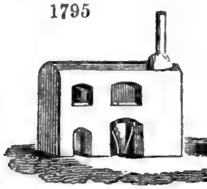
When at length he finds the quicksilver is no longer absorbed, the operation is considered complete, and the torta *rendida*, or ready to be washed, and sometimes lime is added to stop further action. A large quantity of quicksilver is then thrown in, and is called *el baño*, or bath, which combining with the amalgam, causes it to separate the more readily from the slime in the washing. The time required to complete the process varies from ten to thirty days; but in some places is often considerably more, according to climate and the nature of the ore.

The amalgam has now to be separated from the mass, which is done at Real del Monte by washing it in a large square vat, in which several men keep constantly stirring it with their feet, while at the same time a stream of water is made to pass through. By this means the lighter particles of the mud flow out into canals furnished with basins, called *apuros*, to catch all stray amalgam and quicksilver, and the great body of the amalgam remains at the bottom of the vat.

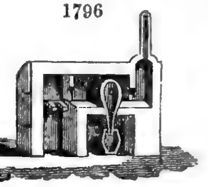
In Guanaxuato, the process of washing is more perfect. They have three circular vats called *tinas*, in which the ore is stirred by means of long wooden teeth fixed in cross bars attached to a vertical shaft, the whole turned by a simple machine, worked by mules. The slime has to pass through the third vat before being carried entirely away, so that a very small portion indeed of the amalgam escapes. The process of washing is somewhat similar in Zacatecas, but there they use but one tina or vat.

The amalgam is carried in bowls into the *azogueria*, where it is subjected to straining through the strong canvas bottom of a leathern bag. The hard mass left in the bag is moulded into wedge-shaped masses of 30 lbs., which are arranged in the burning house (*fig.* 1795), to the number of 11, upon a solid copper stand, called *baso*, having a round hole in its centre. Over this row of wedges several others are built; and the whole pile is called *piña*. Each circular range is firmly bound round with a rope. The base is placed over a pipe which leads to a small tank of water for condensing the quicksilver; a cylindrical space being left in the middle of the piña, to give free egress to the mercurial vapours.

1795



1796



A large bell-shaped cover, called *capellina*, is now hoisted up, and carefully lowered over the piña, by means of pulleys. A strong lute of ashes, saltierra, and lama is applied to its lower edge, and made to fit very closely to the plate on which the base stands. A wall of fire-bricks is then built loosely round the capellina, and this space is filled with burning charcoal, which is thrice replenished, to keep it burning all night. After the heat has been applied 20 hours, the bricks and ashes are removed, the luting broken, and the capellina hoisted up. The burned silver is then found in a hard mass, which is broken up, weighed, and carried to the casting-house, to be formed into bars.

It will be observed that quicksilver performs a very important part in the process of amalgamation, the silver being through its agency collected from the ore: but this is only done by an enormous loss of its own bulk, occasioned in part mechanically from its minute subdivision through such an immense mass of matter, but principally from the chemical action upon it during the reducing process. The consumption of quicksilver varies in different districts, according to the nature of the ores, the climate, and the practical skill attained by the operator.

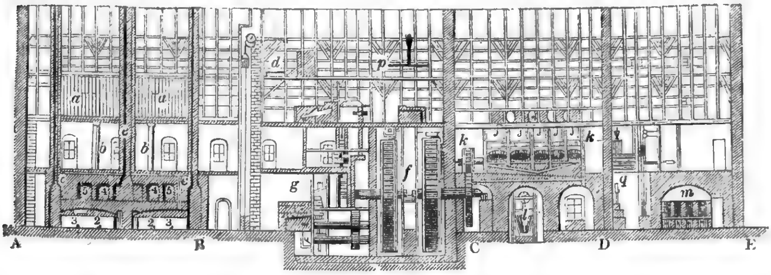
In some places and on some ore the loss of quicksilver is as low as ten ounces for every marc of silver produced, while in others it exceeds 20 ounces; the average loss may, however, be taken to be a pound of quicksilver for every half-pound of silver extracted.

Gay-Lussac, Boussingault, Karsten, and several other chemists of note have offered solutions of the amalgamation enigma of Mexico and Peru. The following seems to be the most probable *rationale* of the successive steps of the process:—

The addition of the *magistral* (powder of the roasted copper pyrites), is not for the purpose of disengaging hydrochloric acid from the sea-salt (*saltierra*), as has been supposed, since nothing of the kind actually takes place; but, by reciprocal or compound affinity, it serves to form chloride of copper and chloride of iron, upon the one hand, and sulphate of soda, upon the other. Were sulphuric acid to be used instead of the magistral, as certain novices have prescribed, it would certainly prove injurious, by causing muriatic acid to exhale. Since the ores contain only at times oxide of silver, but always a great abundance of oxide of iron, the acid would partly carry off both, but leave the chloride of silver in a freer state. A magistral, such as sulphate of iron, which is not in a condition to generate the chlorides, will not suit the present purpose; only such metallic sulphates are useful as are ready to be transformed into chlorides by the saltierra. This is peculiarly the case with sulphate of copper. Its proto-chloride gives up chlorine to the silver, becomes in consequence a subchloride, while the chloride of silver, thus formed, is revived, and amalgamated with the quicksilver present, by electro-chemical agency which is excited by the saline menstruum; just as the voltaic pile of copper and silver is rendered active by a solution of sea-salt. A portion of chloride of mercury will be simultaneously formed, to be decomposed in its turn by the sulphate of silver resulting from the mutual action of the acidified pyrites, and the silver or its oxide in the ore. An addition of quicklime counteracts the injurious effect of too much magistral, by decomposing the resulting sulphate of copper. Quicksilver, when introduced in too great quantities, is apt to cool the mass too much, and thereby enfeebles the operation of the proto-chloride of copper upon the silver.

Washoe Amalgamation Process.—The system of amalgamation largely carried out in the silver-works at Nevada, was originally introduced in the Washoe district, whence it derives its name. The ores having been broken by Blake's stone-breaker, or by hammers, are fed into a stamping-mill, where they are crushed wet. The stuff discharged from the stamps passes to the settling-tanks, in which the finely-suspended ore is allowed to subside. It is then transferred to the amalgamators, which are usually cast-iron pans, of which various forms have been constructed by Varney and Wheeler, Hepburn and Peterson, and other makers. In these pans the ore is ground with hot water and mercury, often with addition of certain 'chemicals,' such as common salt and sulphate of copper. The impure amalgam is discharged from the pan into the separators or settlers, where it is cleansed, and whence it is generally transferred to the agitators. The superfluous mercury having been strained away, the clean amalgam is retorted, the mercury being thus distilled off, whilst the silver remains behind, and after melting is cast into ingots.

1797



Barrel Amalgamation.—The old amalgamation-works at Halsbrücke, near Freiberg, for the treatment of silver ores by mercury, were much admired, and we will therefore give a sketch of their former arrangement. It should be mentioned, however, that the barrel-amalgamation process has not been worked there since 1856.

Fig. 1797 presents a vertical section of this great *Usine* or *Hüttenwerk*, subdivided into four main departments. The first, A, B, is devoted to the preparation and roasting of the matters intended for amalgamation. The second, B, C, is occupied with two successive siftings and the milling. The third, C, D, includes the amalgamation apartment above, and the wash-house of the residuums below. And in the fourth, D, E, is placed the distilling apparatus, where the amalgam is finally delivered.

1. In division A, B; *a*, *a*, is the magazine of salt; *b*, *b*, is the hall of preparation of the ores; on the floor of which they are sorted, interstratified, and mixed with salt; *c*, *c*, are the roasting furnaces; in each of which we see, 1, the fireplace; 2, 3, the reverberatory hearth, divided into two portions, one a little higher than the other, and more distant from the fireplace, called the *drier*; the materials to be calcined fall into it through a chimney, 6. The other part, 2, of the hearth is the calcining area. Above the furnace are chambers of sublimation, 4, 5, for condensing any volatile matters which may escape by the opening 7. *e* is the main chimney.

2. In the division B, C, we have *d*, the floor for the coarse sifting; beneath, that for the fine sieves; from which the matters fall into the hopper, whence they pass down to *g*, the mill-house, in which they are ground to flour, exactly as in a corn-mill, and are afterwards bolted through sieves. *p*, *f*, is the wheel-machinery.

3. The compartment C, D, is the amalgamation-house, properly speaking, where the casks are seen in their places. The washing of the residuums is effected in the shop *l*, below. *k*, *k*, is the compartment of revolving casks.

4. In the division D, E, the distillation process is carried on. There are four similar furnaces, represented in different states, for the sake of illustration. The wooden drawer is seen below, supporting the cast-iron basin, in which the tripod, with its candelabra for bearing the amalgam-saucers, is placed. *q* is a store chamber.

At B, are placed the pulleys and windlass for raising the roasted ore, to be sifted and ground; as also for raising the milled flour, to be transported to the amalgamation-casks. At D, the crane stands for raising the iron bells that cover the amalgamation candelabra.

Details of the Amalgamation Process, as formerly practised at Halsbrücke.—All ores containing more than 7 lbs. of lead, or 1 lb. of copper, per cent., are excluded from this reviving operation (*Anquickverfahren*); because the lead would render the amalgam very impure, and the copper would be wasted. They are sorted for the amalgamation in such a way that the mixture of the poorer and richer ores may contain $7\frac{1}{2}$, or, at most, 8 loths (of $\frac{1}{2}$ oz. each) of silver per 100 lbs. The most usual constituents of the ores are, sulphur, silver, antimonial silver (*Speissglanzsilber*), bismuth, sulphides of arsenic, of copper, iron, lead, nickel, cobalt, zinc, with several earthy minerals. It is essential that the ores to be amalgamated shall contain a certain proportion of sulphur, in order that they may decompose enough sea-salt in the roasting to disengage as much chlorine as to convert all the silver present into chloride. With this view, ores poor in sulphur are mixed with those that are richer, to make up a determinate average. The ore-post is laid upon the *bed-floor*, in a rectangular heap, about 17 ells long and $4\frac{1}{2}$ ells broad (13 yards and $3\frac{1}{2}$); and upon that layer the requisite quantity of salt is let down from the floor above, through a wooden funnel; 40 cwts. of salt being allotted to 400 cwts. of ore. The heap being made up with alternate strata to the desired magnitude, must be then well mixed, and formed into small bings, called *roast-posts*, weighing each from $3\frac{1}{2}$ to $4\frac{1}{2}$ cwts. The annual consumption of salt at Halsbrücke was 6,000 cwts., supplied by the Prussian salt-works.

Roasting of the Amalgamation Ores.—The furnaces appropriated to the roasting of the ore-posts are of a reverberatory class, provided with soot-chambers. They are built alongside the *bed-floor*, and connected with it by a brick tunnel. The prepared ground-ore (*Erzmehl*) is spread out upon the hearth, and dried with incessant turnings over; then the fire is raised so as to kindle the sulphur, and keep the ore red hot for one or two hours; during which time, dense white-grey vapours of arsenic, antimony, and water, are exhaled. The desulphuration next begins, with the appearance of a blue flame. This continues for three hours, during which the ignition is kept up; and the mass is diligently turned over, in order to present new surfaces, and prevent caking. Whenever sulphurous acid ceases to be formed, the finishing calcination is to be commenced with increased firing; the object being now to decompose the sea-salt by means of the metallic sulphates that have been generated, and to convert them into chlorides, with the simultaneous production of sulphate of soda. The stirring is to be continued till the proofs taken from the hearth no longer betray the smell of sulphurous, but of hydrochloric acid gas. This roasting stage commonly lasts three quarters of an hour; 13 or 14 furnaces are worked at the same time at Halsbrücke, and each turns out in a week upon an average 5 tons. Out of the *Nicht* chambers or soot-vaults of the furnaces, from 96 to 100 cwts. of ore-dust are obtained, containing 32 marcs (16 lbs.) of silver. This dust is to be treated like unroasted ore. The fuel of the first fire is pitcoal; of the finishing one fir-wood. Of the former $115\frac{1}{2}$ cubic feet, and of the latter $294\frac{1}{4}$, are, upon an average, consumed for every 100 cwts. of ore.

During the last roasting, the ore increases in bulk by one-fourth, becoming in consequence a lighter powder, and of a brown colour. When this process is completed, the ore is raked out upon the stone pavement, allowed to cool, then screened in close sieve-boxes, in order to separate the finer powder from the lumps. These are to be bruised, mixed with sea-salt, and subjected to another calcination. The finer powder alone is taken to the millstones, of which there are 14 pairs in the establishment. The stones are of granite, and make from 100 to 120 revolutions per minute. The roasted ore, after it has passed through the bolter of the mill, must be as impalpable as the finest flour.

The Amalgamation.—This (the *Verquicken*) is performed in 20 horizontal casks, arranged in 4 rows, each turning upon a shaft which passes through its axis; and all driven by the water-wheel shown in the middle of *fig.* 1797. The casks are 2 feet 10 inches long, 2 feet 8 inches wide, inside measure, and are provided with iron ends. The staves are $3\frac{1}{2}$ inches thick, and are bound together with iron hoops. They have a double bung-hole, one formed within the other, secured by an iron plug fastened with screws. They are filled by means of a wooden spout terminated by a canvas hose; through which 10 cwts. of the boiled ore-flour (*Erzmehl*) are introduced after 3 cwts. of water have been poured in. To this mixture from $\frac{3}{4}$ to $\frac{7}{8}$ of a cwt. of pieces of iron, $1\frac{1}{2}$ inch square, and $\frac{3}{8}$ thick, are added. When these pieces get dissolved, they are replaced by others. The casks being two-thirds full, are set to revolve for $1\frac{1}{2}$ or 2 hours, till the ore-powder and water become a uniform pap; when 5 cwts. of quicksilver are poured into each of them. The casks being again made tight, are put in gear with the driving machinery, and kept constantly revolving for 14 or 16 hours, at the rate of 20 or 22 turns per minute. During this time they are twice stopped and opened, in order to see whether the pap be of the proper consistence; for if too thick, the globules of quicksilver do not readily combine with the particles of ore; and if too thin, they fall and rest at the bottom. In the first case some water must be added; in the second, ore. During the rotation, the temperature rises, so that even in winter it sometimes stands so high as 104° Fahr.

The chemical changes which occur in the casks are the following:—The metallic chlorides present in the roasted ore are decomposed by the iron, whence results chloride of iron, whilst the protochloride of copper is reduced partly to subchloride, and partly to metallic copper, which throw down metallic silver. The mercury dissolves the silver, copper, lead, antimony, in a complex amalgam. If the iron is not present in sufficient quantity, or if it has not been worked with the ore long enough to convert the cupric chloride into a cuprous chloride, previously to the addition of the mercury, more or less of the last metal will be wasted by its conversion into protochloride (calomel). The water holds in solution sulphate of soda, undecomposed sea-salt, with chlorides of iron, manganese, &c.

As soon as the revivification is complete, the casks must be filled with water, set to revolve slowly (about 6 or 8 times in the minute), by which in the course of an hour, or an hour and a half at most, a great part of the amalgam will have collected at the bottom; and in consequence of the dilution, the portion of horn-silver held in solution by the sea-salt will fall down and be decomposed. Into the small plug in the centre of the bung, a tube with a stopcock is now to be inserted, to discharge the amalgam into its appropriate chamber. The cock must be stopped whenever the brown muddy residuum begins to flow. The main bung being then opened, the remaining contents of the casks are emptied into the *wash-tun*, while the pieces of iron are kept back. The residuary ore is found to be deprived of its silver to within $\frac{5}{32}$ or $\frac{7}{40}$ of an ounce per cwt. The emptying of all the casks, and charging them again, takes 2 hours; and the whole process is finished within 18 or 20 hours; namely, 1 hour for charging; 14 to 16 hours for amalgamating; 1½ hour for diluting; 1 hour for emptying. In 14 days 3,200 cwts. of ore are amalgamated. For working 100 cwts. of ore, 14½ lbs. of iron are required; and for every pound of silver obtained, 3 ozs. of mercury are consumed.

Trials have been made to conduct the amalgamation-process in iron casks, heated to 150° or 160° Fahrenheit, over a fire; but although the desilvering was more complete, the loss of mercury was so much greater as to more than counterbalance that advantage.

Treatment of the Amalgam.—It is first received in a moist canvas bag, through which the thin uncombined quicksilver spontaneously passes. The bag is then tied up and subjected to pressure. Out of 20 casks, from 3 to 3½ cwts. of solid amalgam are thus procured, which usually consist of 1 part of an alloy, containing silver of 12 or 13 *loths* (in 16), and 6 parts of quicksilver. The foreign metals in that alloy are copper, lead, gold, antimony, cobalt, nickel, bismuth, zinc, arsenic, and iron. The filtered quicksilver contains moreover 2 to 3 loths of silver in the cwt.

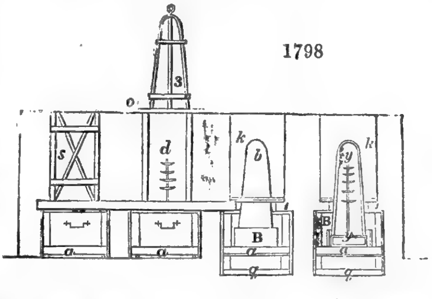

1798

Fig. 1798 represents the apparatus formerly used for distilling the amalgam in the Halsbrücke works. *a* is the wooden drawer, sliding in grooves upon the basis, *q*; B is an open basin or box of cast iron, laid in the wooden drawer; *y* is a kind of iron candelabrum, supported upon four feet, and set in the basin, B; under *d* are five dishes or plates, of wrought iron, with a hole in the centre of each, by which they are fitted upon the stem of the candelabrum, 3 inches apart, each plate being successively smaller than the one below it. 3 indicates a cast-iron bell, furnished with a wrought-iron frame and hook, for raising it by means of a pulley and cord. *s* is a sheet-iron door for closing the stove, whenever the bell has been set in its place.

The box, *a*, and the basin, B, above it, are filled with water, which must be continually renewed, through a pipe in the side of the wooden box, so that the iron basin may be kept always submersed and cool. The drawer, *a*, being properly placed, and the plates under *d* being charged with balls of amalgam (weighing altogether 3 cwts.), the bell, 3, is to be let down into the water, as at *y*, and rested upon the lower part of the candelabrum. Upon the ledge, 1, which defines the bottom of the fireplace, a circular plate of iron is laid, having a hole in its middle for the bell to pass through.

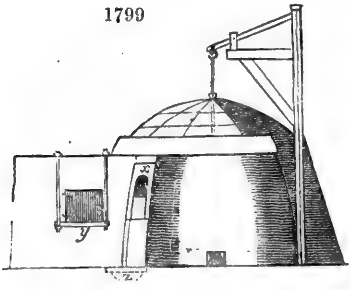
Upon this plate chips of fir-wood are kindled, then the door, *s*, which is lined with clay, is closed and luted tight. The fuel is now placed in the vacant space, *k*, round the upper part of the bell. The fire must be fed-in most gradually, first, with turf, then with charcoal; whenever the bell gets red, the mercury volatilises, and condenses in globules into the bottom of the basin, B. At the end of 8 hours, should no more drops of mercury be heard to fall into the water, the fire is stopped. When the bell has become cool, it is lifted off; the plates are removed from the candelabrum, *d*; and this being taken out, the drawer, *a*, is slid away from the furnace. The mercury is drained, dried, and sent again into the amalgamation-works. The silver is fused and refined by cupellation.

From 3 cwts. of amalgam, distilled under the bell, from 95 to 100 marcs ($\frac{1}{2}$ lbs.) of *Tellersilber* (dish-silver) are procured, containing from 10 to 13$\frac{1}{2}$ parts of fine silver out of 16; one fifth part of the metal being copper. The teller silver is refined in quantities of 160 or 170 marcs, in black-lead crucibles filled within two inches of their brims, and submitted to brisk ignition. The molten mass exhales some vapours, and throws up a liquid slag, which being skimmed off, the surface is to be strewed over with charcoal-powder, and covered with a lid. The heat having been briskly urged for a short time, the charcoal is then removed along with any fresh slag that may have risen, in order to observe whether the vapours have ceased. If not, fresh charcoal must be again applied, the crucible must be covered, and the heat increased, till fumes are no longer produced, and the surface of the silver becomes tranquil. Finally, the alloy, which contains a little gold, and much copper, being now from 11 to 13 *löthig* (that is, holding from 11 to 13 parts of fine silver in 16 parts), is cast into iron moulds, in ingots of 60 marcs. The loss of weight by evaporation and skimming of the slag amounts to 2 per cent.; the loss in silver is inconsiderable.

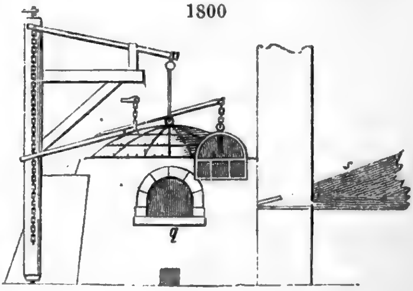
The dust from the furnace (*Tiegelofen*) is collected in a large condensation chamber of the chimney, and affords from 40 to 50 marcs of silver per cwt. The slags and old crucibles are ground and sent to the small amalgamation mill.

The earthy residuum of the amalgamation casks being submitted to a second amalgamation, affords out of 100 cwts. about 2 lbs. of coarse silver. This is first fused along with three or four per cent. of a mixture of potash and calcined *Quicksalz* (impure sulphate of soda), and then refined. The supernatant liquor that is drawn out of the tanks in which the contents of the casks are allowed to settle, consists chiefly of sulphate of soda, along with some common salt, sulphates of iron and manganese, and a little phosphate, arsenate, and fluoride of sodium. The earthy deposit contains from $\frac{1}{4}$ to $\frac{2}{32}$nds of a loth of silver per cwt., but no economical method of extracting this small quantity was used.

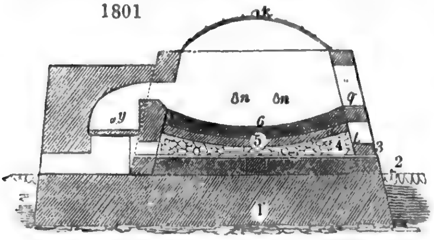
1799



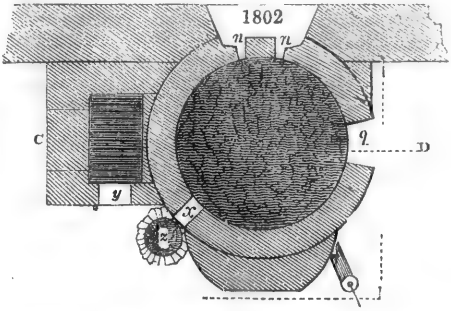
1800



1801



Argentiferous or *rich lead* is treated in Germany by the cupellation furnace represented in *figs.* 1799, 1800, 1801, and 1802. These figures exhibit the cupellation furnace of the principal smelting work in the Hartz, where the following parts must be distinguished: (*fig.* 1801) 1, masonry of the foundation; 2, flues for the escape of moisture; 3, stone covers of the flues; 4, bed of hard-rammed scoriæ; 5, bricks set on edge, to form the permanent area of the furnace; 6, the sole, formed of wood-ashes, washed, dried, and beaten down; *k*, dome of iron plate, moveable by a crane, and susceptible of being lined two inches thick with loam; *n*, *n*, tuyères for two bellows, *s*, having valves suspended before their orifices to break and spread the blast; *q*, door for introducing into the furnace the charge of lead, equal to 84 quintals at a time; *s*, *fig.* 1800, two bellows, like those of a smith's forge; *y*, door of the fireplace, through which billets of wood are thrown on the grate; *x*, small aperture or door, for giving issue to the frothy scum of the cupellation, and the litharge; *z*, basin of safety, usually covered with a stone slab, over which the litharge falls: in case of accident the basin is laid open to admit the *rich lead.*


1802

The following is the mode of conducting the cupellation:—Before putting the lead into the furnace, a floor is made in it of ashes beaten carefully down (see *fig.* 1801); and there is left in the centre of this floor a circular space, somewhat lower than the rest of the hearth, where the silver ought to gather at the end of the operation. The cupel is fully 6 feet in diameter.

In forming the floor of a cupel, 35 cubic feet of washed wood-ashes, usually got from the soap-works, are employed. The preparation of the floor requires two and a half hours' work; and when it is completed, and the moveable dome of iron plate has been lined with loam, 84 quintals (cwts.) of lead are laid on the floor, 42 quintals being placed in the part of the furnace farthest from the bellows, and 42 near to the fire-bridge; to these, scoriæ containing lead and silver are added, in order to lose nothing. The moveable lid is now luted on the furnace, and heat is slowly applied in the fire-place by burning fagots of fir-wood; this is gradually raised. Section *fig.* 1801, is in the line C, D, of *fig.* 1802.

At the end of three hours, the whole lead being melted, the instant is watched for when no more ebullition can be perceived on the surface of the bath or melted metal; then, but not sooner, the bellows are set a-playing on the surface at the rate of four or five strokes per minute, to favour the oxidation.

In five hours, reckoned from the commencement of the process, the fire is smartly raised; when a greyish froth (*Abstrich*) is made to issue from the small aperture *x*, of the furnace. This is found to be a brittle mixture of oxidised metals and impurities. The workman now glides the rake over the surface of the bath, so as to draw the froth out of the furnace; and as it issues, powdered charcoal is strewed upon it at the aperture *x*, to cause its coagulation. The froth-skimming lasts for about an hour and a half.

After this time the litharge begins to form, and it is also led off by a small opening *x*, its issue being aided by a hook. In proportion as the floor of the furnace gets impregnated with litharge, the workman digs in it a gutter for the escape of the liquid litharge; it falls in front of the small aperture, and concretes in stalactitic forms.

By means of the two moveable valves suspended before the tuyères *n*, *n* (*fig.* 1802), the workman can direct the blast as he wishes over the surface of the metal. The wind should be made to cause a slight curl on the liquid, so as to produce circular undulations, and gradually propel a portion of the litharge generated towards the edges of the cupel, and allow this to retain its shape till the end of the operation. The stream of air should drive the greater part of the litharge towards the small opening *x*, where the workman deepens the outlet for it, in proportion as the level of the metallic bath descends. Litharge is thus obtained during about twelve hours; after which period the cake of silver begins to take shape in the centre of the cupel.

Towards the end of the operation, when no more than four additional quintals of litharge can be looked for, and when it forms solely in the neighbourhood of the silver cake in the middle of the floor, great care must be taken to set apart the latter portions, because they contain silver. About this period the fire is increased, and the workman places before the little opening *x*, a brick, to serve as a mound against the efflux of litharge. The use of this brick is,—1, to hinder the escape of the silver in case of any accident; for example, should an explosion take place in the furnace; 2, to reserve a magazine of litharge, should that still circulating round the silver cake be suddenly absorbed by the cupel, for in this dilemma the litharge must be raked back on the silver; 3, to prevent the escape of the water that must be thrown on the silver at the end of the process.

When the argentiferous litharge, collected in the above small magazine, is to be removed, it is let out in the form of a jet, by the dexterous use of the iron hook.

Lastly, after twenty hours, the silver cake is seen to be well formed, and nearly circular. The moment for stopping the fire and the bellows is indicated by the sudden disappearance of the coloured particles of oxide of lead, which, in the latter moments of oxidation, undulate with extreme rapidity over the slightly convex surface of the silver-bath, moving from the centre to the circumference. The phenomenon of their total disappearance is called the *lightning*, or *brightening* (*Blick*). Whenever this occurs, the plate of silver being perfectly clean, there is introduced into the furnace by the door *q*, a wooden spout, along which water, previously heated, is carefully poured on the silver.

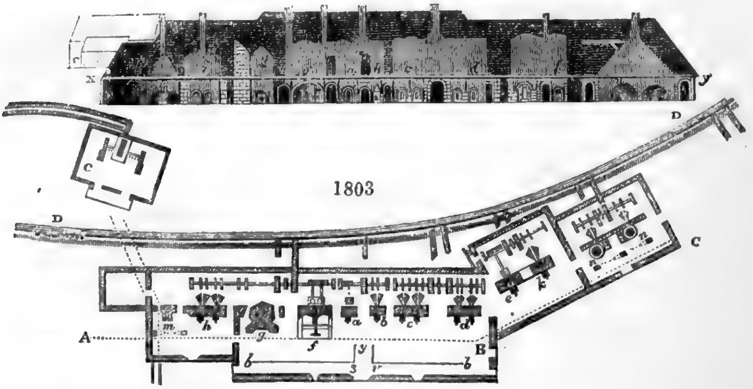
The cupellation of 84 quintals of argentiferous lead takes in general eighteen or twenty hours. The promptitude of the operation depends on the degree of purity of the leads employed, and on the address of the operator, with whom also lies the economy of fuel. A good workman completes the cupellation of 84 quintals with 300 billets, each equivalent to a cubic foot and $\frac{8}{10}$ths of wood (Hartz measure); others consume 400 billets, or more. In general, the cupellation of 100 quintals of lead, executed at the rate of 84 quintal charges, occasions a consumption of 790 cubic feet of resinous wood-billets.

The products of the charge are as follow:—

1. Silver, holding in 100 marcs, 7 marcs and 3 loths of alloy .	24 to 30 marcs.
2. Pure litharge, containing from 88 to 90 per cent. of lead .	50 ,, 60 quintals.
3. Impure litharge, holding a little silver	2 ,, 6
4. Skimmings of the cupellation	4 ,, 8
5. Floor of the furnace impregnated with litharge . . .	22 ,, 30

The marc is 7 oz. 2 dwts. 4 grs. English troy; and the loth is half an ounce. 16 loths make a marc. 100 lbs. Cologne are equal to 103 lbs. avoirdupois; and the above quintal contains 116 Cologne lbs.

The loss of lead inevitable by this operation is estimated at 4 parts in 100. It has been diminished as much as possible in the Frankenscharn works of the Hartz, by leading the smoke into long flues, where the lead-fumes are condensed into a metallic soot.


1803

Reduction of the litharge.—This is sometimes executed in a slag-hearth, with the aid of wood-charcoal.

The following is the series of operations:—

1. The fusion of the schlich; 2, the roasting of the matts under a shed, and their treatment by four successive smeltings; 3, the treatment of the resulting black copper; 4, the liquation; 5, the reliquation (*ressuage*); 6, the refining of the copper; 7, the cupellation of the silver; 8, the reduction of the litharge into lead. The fifth and sixth processes are carried on at the smelting-works of Altenau.

The buildings are shown at A, B, C, and the impelling stream of water at D (*fig.* 1803): the upper figure being the elevation; the lower, the plan of the works.

a, is a melting furnace, with a cylinder bellows behind it; *b*, *c*, *d*, furnaces similar to the preceding, with wooden bellows, such as *fig.* 1804; *e*, is a furnace for the same purpose, with three tuyères, and a cylinder bellows; *f*, the large furnace of fusion, also with three tuyères; *g*, a furnace with seven tuyères, now seldom used; *h*, low furnaces, like the English slag-hearths (*Krummöfen*), employed for working the last *mattes*; *k*, slag-hearths for reducing the litharge; *m*, the area of the liquation; *n*, *n*, cupellation furnaces.

x, *y*, a floor which separates the principal smelting-houses into two stories; the materials destined for charging the furnaces being deposited in beds upon the upper floor, to which they are carried by means of two inclined planes, terraced in front of the range of buildings.

1804

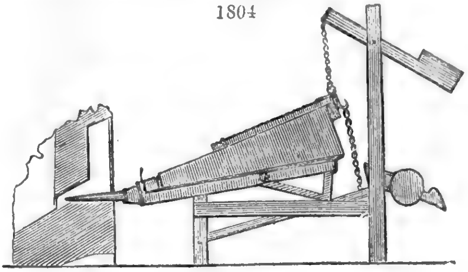
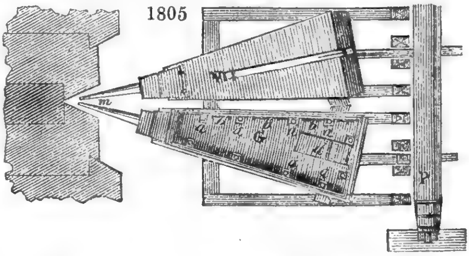
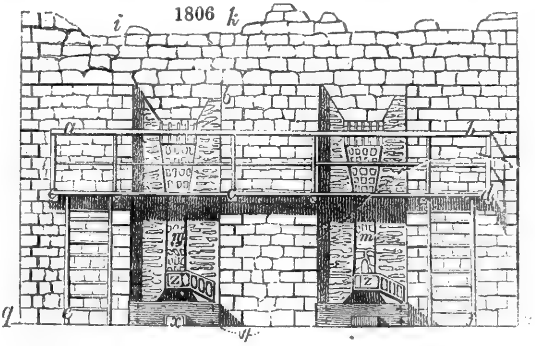


Fig. 1805 represents such wooden bellows, consisting of two chests or boxes, fitted into each other; the upper or moving one being called the *fly*, the lower or fixed one the *seat* (*gîte*). In the bottom of the gîte there is an orifice furnished with a clack-valve, *d*, opening inwards when the fly is raised, and shutting when it falls. In order that the air included in the capacity of the two chests may have no other outlet than the nose-pipe *m*, the upper portion of the gîte is provided at its four sides with small square slips of wood, *c*, *c*, *c*, which are pressed against the sides of the fly by strong springs of iron wire, *b*, *b*, *b*, while they are retained upon the gîte by means of small square pieces of wood, *a*, *a*, *a*, *a*. The latter *a*, *a*, are perforated in the centre, and adjusted upon rectangular stems, called *buchettes*; they are attached, at their lower ends, to the upright sides of the gîte G. P is the driving-shaft of a water-wheel, which, by means of cams or tappets, depresses the fly, while the counterweight Q, raises it again.

1805



1806

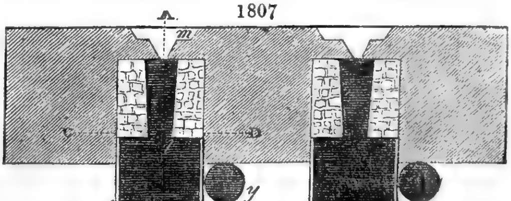


Figs. 1806 to 1809 represent the moderately high (*demi-hauts*, or *half-blast*) furnaces employed in the works of the Lower Hartz, near Goslar, for smelting the silvery lead ore extracted from the mine of Rammelsberg.

Fig. 1806 is the front elevation of the twin furnaces, built in one body of masonry; *fig.* 1807 is a plan taken at the level of the tuyères.

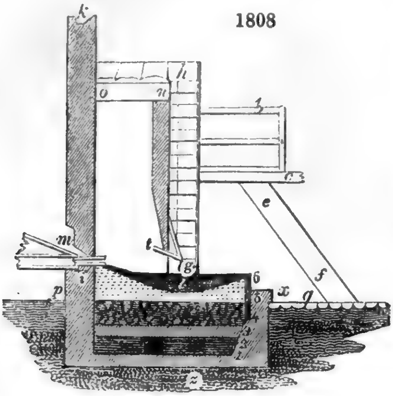
Figs. 1808 and 1809 exhibit two vertical sections; the former in the line A, B, the latter in the line C, D, of *fig.* 1807. In these four figures the following objects may be distinguished:—

1807

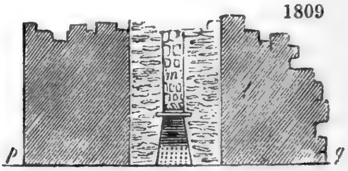


a, b, c, d, a balcony or platform, which leads to the place of charging, *n*; *e, f*, wooden stairs, by which the workmen charging mount from the ground, *p, q*, of the works, to the platform; *g, h*, brickwork of the furnaces; *i, k*, wall of the smelting-works, against which they are supported; *l*, upper basin of reception, hollowed out of the *brasque* (or bed of ground charcoal and clay) 6; *m*, arch of the tuyère v, by which each furnace receives the blast of two bellows; *n*, place of charging, which takes place through the upper orifice *n, o*, of the basin *n, o*, v, *t*, of the furnace; *t*, a sloping gutter, seen in *fig.* 1808, formed of slates cemented together with clay.

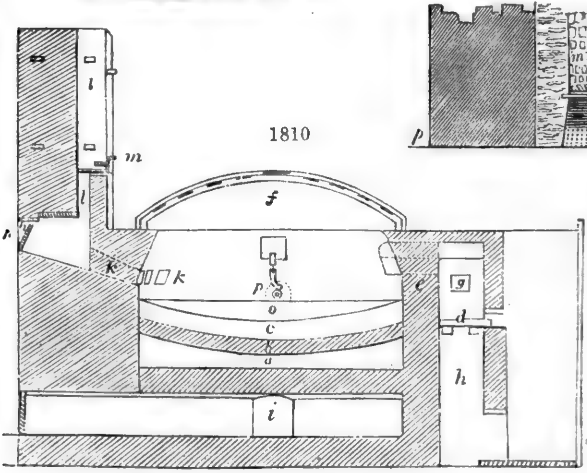
In *figs.* 1808 and 1809, *z* is the brickwork of the foundations; *m*, conduits for the exhalation of moisture; 4, a layer of slags, rammed above; 5, a bed of clay, rammed above the slags; 6, a brasque, composed of one part of clay and two parts of ground charcoal, which forms the sole of the furnace.



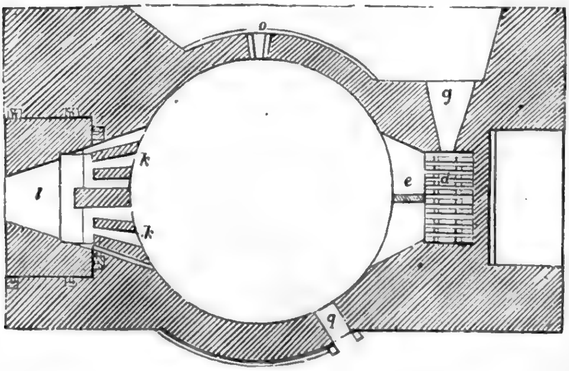
1809



1810

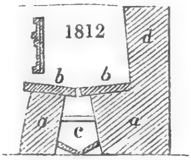


1811

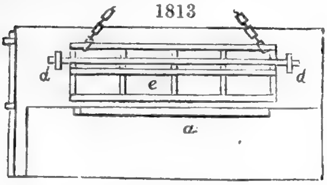


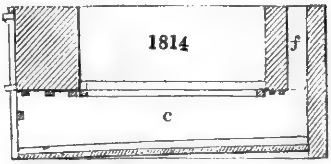
The refinery furnace, or *Treibheerd*, of Friedrichshütte, near Tarnowitz, in Upper Silesia, is represented in *figs.* 1810 and 1811. *a*, is the bottom, made of slag or cinders; *b*, the foundation, of fire-bricks; *c*, the body of the hearth proper, composed of a mixture of 7 parts of dolomite and 1 of fire-clay, in bulk; *d*, the grate of the air-furnace; *e*, the fire-bridge; *f*, the dome or cap, made of iron-plate strengthened with bars, and lined with clay-lute, to protect the metal from burning; *g*, the door of the fireplace; *h*, the ash-pit; *i*, the tap-hole; *k*, *k*, the flue, which is divided by partitions into several channels; *l*, the chimney; *m*, a damper-plate for regulating the draught; *n*, a back valve, for admitting air to cool the furnace, and brushes to sweep the flues; *o*, tuyère of copper, which by means of an iron wedge may be sloped more or less towards the hearth; *p*, the *Schnepper*, a round piece of sheet iron, hung before the *eye* of the tuyère, to break and spread the blast; *q*, outlet for the glassy litharge.

Lime-marl has been found to answer well for making the body of the hearth-sole as it absorbs litharge freely, without combining with it. A basin-shaped hollow is formed in the centre, for receiving the silver at the end of the process; and a gutter is made across the hearth for running off the *Glätte* or fluid litharge.


1812

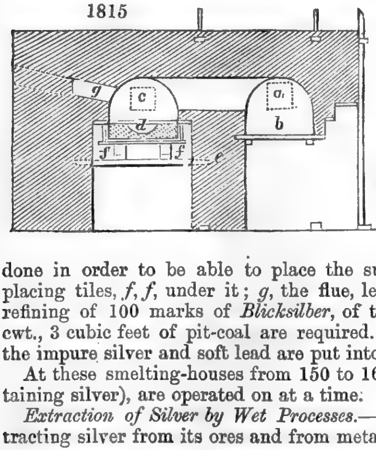
Figs. 1812 to 1814 represent the eliquation hearth of Neustadt. *Fig.* 1812 is a cross-section; *fig.* 1813 is a front view; and *fig.* 1814 a longitudinal section. It is formed by two walls, *a*, *a*, 3½ feet high, placed from ½ to 1 foot apart, sloped off at top with iron-plates, 3 inches thick and 18 inches broad, called *Saigerscharten*, or refining plates, *b*, *b*, inclined 3 inches towards each other in the middle, so as to leave at the lowest point a slit 2½ inches wide between them, through which the lead, as it sweats out by the heat, is allowed to fall into the space between the two walls c, called the *Saigergasse* (sweating-gutter). The sole of this channel slopes down towards the front, so that the liquefied metal may run off into a crucible or pot. Upon one of the long sides, and each of the shorter ones, of the hearth the walls *d*, *d*, are raised 2 feet high, and upon these the liquidation lumps rest; upon the other long side, where there is no wall, there is an opening for admitting these lumps into the hearth. The openings are then shut with a sheet- or cast-iron plate *e*, which, by means of a chain, pulley, and counter-weight, may be easily raised and lowered. *f* is a passage for increasing the draught of air.


1813

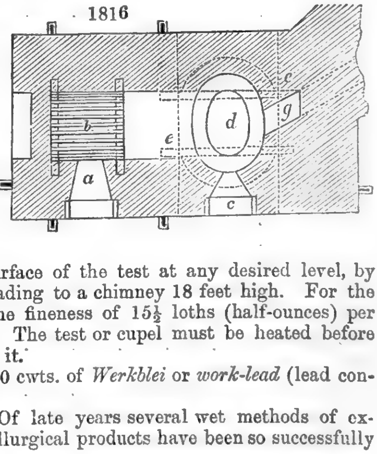

1814

Figs. 1815 and 1816 represent the refining furnaces of Friedhricshütte, near Tarnowitz: *a*, is the fire-door; *b*, the grate; *c*, the door for introducing the silver; *d*, the moveable test, resting upon a couple of iron rods, *e*, *e*, which are let at their ends into the brickwork. They lie lower than would seem to be necessary; but this is done in order to be able to place the surface of the test at any desired level, by placing tiles, *f*, *f*, under it; *g*, the flue, leading to a chimney 18 feet high. For the refining of 100 marks of *Blicksilber*, of the fineness of 15½ loths (half-ounces) per cwt., 3 cubic feet of pit-coal are required. The test or cupel must be heated before the impure silver and soft lead are put into it.

1815



1816



At these smelting-houses from 150 to 160 cwts. of *Werkblei* or *work-lead* (lead containing silver), are operated on at a time.

Extraction of Silver by Wet Processes.—Of late years several wet methods of extracting silver from its ores and from metallurgical products have been so successfully employed as to supplant, in many cases, the old processes of amalgamation and liquation previously described. The principal wet processes which have been largely used, are those of Augustin, Ziervogel, and Von Patera.

Augustin's Process.—The argentiferous ore, or the matt or regulus, is first roasted with common salt, whereby the silver passes into the state of chloride, which is then dissolved out by a hot concentrated solution of salt; chloride of silver being soluble in hot brine. From this solution, the silver is precipitated by means of metallic copper. This process was introduced at the Mansfeld Kupferschiefer works, in Prussian Saxony, by Augustin, in 1849, but was abandoned in 1857. It was used at Freiberg, in Saxony, between the years 1849 and 1862.

Ziervogel's Process.—By roasting the argentiferous copper-matts, from the smelting of the Kupferschiefer, in a reverberatory furnace, the iron is converted into sulphate, which is then decomposed and yields peroxide of iron; the copper also forms sulphate, which is afterwards reduced to black oxide; and in like manner, the silver present as sulphide is oxidised to the state of sulphate. When, therefore, the roasted product is lixiviated with hot water, the sulphate of silver is freely dissolved out, whilst the oxides of copper and iron remain insoluble. The silver is precipitated in the metallic form by means of copper. This is the process still employed at the Gottesbelohnungshütte Silver-extraction works, near Mansfeld.

Von Patera's Process.—This method is based on a suggestion made by Dr. Percy in 1848. The ore is first roasted with common salt, whereby chloride of silver is directly formed, and this chloride is then dissolved out by a cold dilute solution of hyposulphite of soda. The silver is precipitated from this solution as sulphide, by addition of sulphide of sodium; and the silver sulphide is afterwards reduced to metallic silver by heating in a muffle-furnace. This process was introduced by Von Patera at Joachimstahl, in Bohemia, in 1858, and is believed to be still working.

Sulphuric Acid Method.—Argentiferous copper-matts are treated with hot dilute sulphuric acid, whereby sulphate of copper is formed, and passes into solution, whilst most of the silver and gold present is left in the residues. These are then smelted with lead-ores, and the silver extracted from the argentiferous lead. This process is now employed at Oker, in the Lower Hartz.

Pattinson's process for extracting silver from argentiferous lead is fully described under Silver; and Claudet's recent process for recovering silver from the liquors obtained in the wet treatment of coppery pyrites, is duly noticed under Pyrites.

The following statement of the production of silver in all parts of the world is given by Mr. J. Arthur Phillips, chiefly on the authority of Duport and Chevalier. See Phillips's 'Gold and Silver':—

Places	1865 lbs. troy	Ratio per cent.
Russian Empire	58,000	1·5
Scandinavia	15,000	0·4
Great Britain	60,500	1·5
Hartz	28,000	0·6
Prussia	68,000	1·7
Saxony	80,000	2·0
Other German States	2,500	
Austria	92,000	2·2
France	18,000	0·4
Italy	25,000[1]	0·6
Spain	110,000	2·8
Australia, New Zealand, British Columbia, and Nova Scotia	9,500	0·2
Chili	299,000	7·3
Bolivia	136,000	3·3
Peru	299,000	7·4
New Granada	15,000	0·4
Brazil	1,500	0·4
Mexico	1,700,000	42·3
United States	1,000,000	25·0
Total	4,017,000	10·0

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[1] Obtained from the island of Sardinia, where it is found associated with galena.

The Production of Silver in the United Kingdom has been as follows in the last five years.

	1869	1870	1871	1872	1873
England:	ozs.	ozs.	ozs.	ozs.	ozs.
Cornwall	315,714	292,045	267,324	207,710	129,509
Devonshire	27,437	24,706	13,805	10,392	6,510
Derbyshire	1,000	950	1,000	1,000	750
Shropshire	...	...	...	2,960	2,400
Yorkshire	990	620	305	500	1,500
Cumberland	25,236	23,387	47,179	30,159	16,175
Westmoreland	26,883	23,096	28,969	17,620	16,850
Durham and Northumberland.	85,398	78,742	75,776	72,175	47,862
Wales:					
Cardiganshire. . . .	66,145	56,553	46,980	41,690	39,869
Caermarthenshire . . .	2,592	2,365	3,180	2,382	2,518
Pembrokeshire . . .	4,050	3,847	1,872	490	1,341
Radnorshire	...	...	...	125	...
Montgomeryshire . . .	30,218	42,670	48,145	55,712	54,957
Merionethshire . . .	...	180	...	...	110
Denbighshire	28,952	26,512	21,805	14,479	11,339
Flintshire	30,617	27,745	22,787	18,650	12,337
Carnarvonshire . . .	480	121	447	500	2,082
Isle of Man	172,839	172,528	176,631	145,433	163,058
Ireland	5,480	2,815	...	1,040	4,420
Scotland	7,797	5,680	5,285	5,900	10,720
Total . . .	831,891	784,562	761,490	628,920	524,307

The Silver Imported in 1873 *was as follows:—*

	Tons	Value
From Spain	837	£22,000
„ United States of America .	1,479	163,197
„ Mexico.	106	16,019
„ New Granada	158	10,869
„ Peru	691	45,027
„ Bolivia.	4,270	405,155
„ Chili	4,100	342,066
„ Other countries . . .	305	16,260
Total . . .	11,946	1,020,593

SILVER ASSAYING. This may be conveniently divided into: 1. The assaying of silver ores; 2. The assaying of silver and its alloys.

1. *The assaying of silver ores.*—The ores are reduced to fine powder, and passed through a sieve of 80 holes to the linear inch, and any residual metalliferous particles carefully collected and submitted to a separate assay. The total weight of the sample is ascertained, in order that the proportion of silver obtained from the residue may be calculated. The sifted portion is well mixed, and submitted to assay by one of the following methods:—

a. Fusion Method.—This process is conducted in crucibles, in an air-furnace similar to that described in *fig.* 533, p. 941, vol. i. (See Copper.)

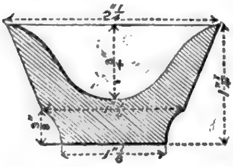
In the assay of silver ores not containing lead, it is usual to obtain the silver they afford in the form of an alloy with lead; and this is subsequently passed to the cupel in the ordinary way. For the assaying of lead ores containing silver, see Lead.

Ores of silver in which the associated metals exist in the form of oxides are commonly fused with a mixture of litharge or red lead, and powdered charcoal, by which an alloy of lead is obtained, which is afterwards treated by cupellation. The amount of litharge employed must be varied according to circumstances, as the resulting button should not be too small, since in that case a portion of the silver might be lost in the slag; nor too large, as the cupellation would then occupy a longer time.

In most cases, if from 100 to 400 grains of ore be operated on, a button of 200 grains will be a convenient weight for cupellation; this may be obtained by the addition of 400 grains of litharge, and from 7 to 8 grains of pulverised charcoal. This is to be well mixed with 200 grains of carbonate of soda, and introduced into an earthen crucible, of which it should not fill more than one-half the capacity. This is covered by a layer of borax, and fused in the assay-furnace, taking care to remove it from the fire as soon as a perfectly liquid slag has been obtained, since the unreduced litharge might otherwise cut through the crucible and spoil the assay. When cold, the pot is broken, and the button of lead cupelled in the ordinary way, or the liquid-products are poured out into a mould (*fig.* 534, see COPPER), and when cold, the slag is detached from the lead.

In this, and all other similar experiments, it is necessary to ascertain the proportion of silver contained in the lead obtained from the litharge used, in order to make the requisite deduction from the results obtained. When other minerals than oxides are to be examined, the addition of charcoal becomes in many cases unnecessary, since litharge readily attacks all the sulphides, arsenio-sulphides, &c., and oxidises many of their constituents, whilst a proportionate quantity of metallic lead is set free. The slags thus formed contain the excess of litharge, and the button of alloy obtained is cupelled. The proportion of oxide of lead to be added to ores of this description varies in accordance with the amounts of oxidisable substances present; but it must always be added in excess in order to prevent any chance of loss of silver from the action of sulphides in the slags. The only objection to this method of assay is the large quantity of lead produced for cupellation, since iron pyrites afford by the reduction of the litharge 8½ parts of lead, whilst sulphide of antimony and grey copper ore yield from 6 to 7 parts. This inconvenience may be obviated by the previous oxidation of the mineral, either by roasting, or by the aid of nitre, by the judicious employment of which, buttons of almost any required weight may be obtained. Should this reagent be employed in excess, it would cause the oxidation of all the metallic and combustible substances present, not even excepting the silver. When, however, the mixture contains at the same time a large excess of litharge, and the quantity of nitre added is not sufficient to decompose the whole of the sulphides, a reaction takes place between the undecomposed sulphide and the oxide of lead added, which gives rise to the formation of metallic lead, and this combining with the silver, affords a button of alloy, which may be treated by cupellation. The quantity of nitre to be used for this purpose will depend on the nature and richness of the ores under examination; but it must be remembered that 2½ parts of nitre will decompose and completely oxidise pure iron pyrites, whilst 1½ and ⅔rds of its weight are in the case of sulphide of antimony and galena respectively sufficient. In cases where the excess of sulphur present is very great, a partial roasting of the ore is preferable to the addition of a large quantity of nitre. Instead of operating according to any of the processes above described, it is sometimes found advantageous to expel the whole of the arsenic and sulphur, by a careful roasting, and then to fuse the residue with a mixture of litharge, carbonate of soda, and borax, taking care to add a sufficient amount of some reducing flux to obtain a button of convenient size. When, in addition to silver, the mineral operated on contains gold, the button obtained by cupellation will consist of a mixture of these metals, which may be separated by the aid of nitric acid. See GOLD ASSAYING.

1816 *a*



b. Scorification Method.—This process is conducted in a muffle-furnace. A cup-shaped vessel or scorifier of fire-clay is employed, which varies in size according to the quantity of ore operated on. The scorifier represented in *fig.* 1816 *a* is 2¼ inches in diameter at the top, and the internal cavity is ¾ of an inch in depth. Tongs of peculiar construction, and varying from 2 feet 3 inches to 3 feet in length, are used for lifting the scorifiers, the lower leg being divided near the end into a two-pronged fork, in order to grasp the lower part of the vessel, while the upper leg is made straight, and holds it firmly on the upper surface. Scorification is a roasting-fusion process. The sulphur and other oxidisable substances present are roasted or decomposed by the oxide of lead produced, and atmospheric air. When these are decomposed, the oxide of lead produces a fusible slag with the silica and other matters present in the ore. The silver alloys with the lead retained in the lower part of the scorifier. The process may be conducted as follows:—50 or 100 grs. of the finely-divided ore are weighed out and transferred to the scorifier. The ore is now mixed with about half of the finely-granulated lead required for the assay, and the other portion is afterwards placed upon the top. From 10 to 20 times its weight of lead is used, according to the nature of the vein-stuff, and minerals present; a small quantity of borax is also added. The scorifier is now placed in a muffle, and the heat increased until fusion occurs. The door of the muffle is now partly removed, in order to admit more air, and allow the oxidation of the lead and other substances to proceed. When the surface of the lead is covered with slag, the scorifier is removed, and its contents poured into an iron mould, see *fig.* 534 (COPPER). When cold, the slag is detached, the lead submitted to cupellation, and the button of silver weighed. The button of lead should be soft and malleable, and from 200 to 300 grs. in weight; larger buttons should be reduced in weight by rescorifying. The slag should be free from small lumps, and perfectly fused before pouring. All silver ores may be assayed by this method, and several assays made at one time, but a fusion-method is preferable for ores poor in silver. Where a number of assays are made by the scorification process, a muffle-furnace of somewhat larger dimensions is constructed than that described under the Assaying of Silver Alloys. With poor ores, four or more scorifiers are charged with weighed portions of ore and lead, and the resulting buttons of lead reduced to one button by repeated scorification, and then finally cupelled. Correction must be made for the silver contained in the amount of granulated lead employed.

In England the results obtained from the assays are reported to ounces, pennyweights, and grains troy, upon the statute ton of 2,240 lbs. The calculations may be made by the following Table:—

Table showing the weight of silver to the ton of ore or alloy corresponding to the weight in grains obtained from 400 *grains of the substance operated on.*

If 400 grains give fine metal,	One ton will yield			If 400 grains give fine metal,	One ton will yield		
grains	ozs.	dwts.	grs.	grains	ozs.	dwts.	grs.
·001	0	1	15	·600	49	0	0
·002	0	3	6	·700	57	3	8
·003	0	4	21	·800	65	6	16
·004	0	6	12	·900	73	10	0
·005	0	8	4	1·000	81	13	8
·006	0	9	19	1·500	122	10	0
·007	0	11	10	2·000	163	6	16
·008	0	13	1	2·500	204	3	8
·009	0	14	16	3·000	245	0	0
·010	0	16	8	3·500	285	16	16
·020	1	12	16	4·000	326	13	8
·030	2	9	0	4·500	367	10	0
·040	3	5	8	5·000	408	6	16
·050	4	1	16	5·500	449	3	8
·060	4	18	0	6·000	490	0	0
·070	5	14	8	6·500	530	16	16
·080	6	10	16	7·000	571	13	8
·090	7	7	0	7·500	612	10	0
·100	8	3	8	8·000	653	6	16
·200	16	6	16	8·500	694	3	8
·300	24	10	0	9·000	735	0	0
·400	32	13	8	9·500	775	16	6
·500	40	16	16	10·000	816	13	8

2. *The Assaying of Silver and its Alloys.*—This is conducted by the dry and wet methods.

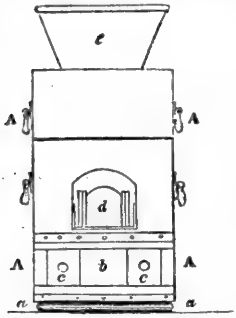
a. Dry Method—by Cupellation (*Coupellation*, Fr.; *Abtreiben auf der Cupelle*, Ger.). The assay by this method is made upon a cupel, and the process is conducted in a cupellation-furnace, or a muffle-furnace. The art of assaying silver by the cupel is founded upon the feeble affinity which this metal has for oxygen, in comparison with lead and copper, and other metals; and on the tendency which the latter metal has to oxidise rapidly in contact with lead at a high temperature, and sink with it into any porous earthy vessel in a thin glassy or vitriform state. The porous vessel may be made either of wood-ashes, freed from their soluble matter by washing with water; or, preferably, of burned bones, or bone-ash, reduced to a fine powder. The cupels allow the fused oxides to be absorbed into them like a sponge, but are impermeable to the particles of metals; and thus the former pass readily down into their substance, while the latter remain upon their surface: a phenomenon owing to the circumstance of the oxides moistening, as it were, the bone-ash powder, whereas the metals can contract no adherence with it. Hence also the liquid metals preserve a hemispherical shape in the cupels, as quicksilver does in a cup of glass, while the fused oxide spreads over, and penetrates their substance, like water.

If we put into a cupel, therefore, two metals, of which the one is unalterable in the air, the other susceptible of oxidisement, and of producing a very fusible oxide, it is obvious that, by exposing both to a proper degree of heat, we shall succeed in separating them. We should also succeed, though the oxide were infusible, by placing it in contact with another one, which may render it fusible. In both cases, however, the metal from which we wish to part the oxides must not be volatile: it should also melt, and form a button at the heat of cupellation; for, otherwise, it would continue disseminated, attached to the portion of oxide spread over the cupel, and incapable of being collected.

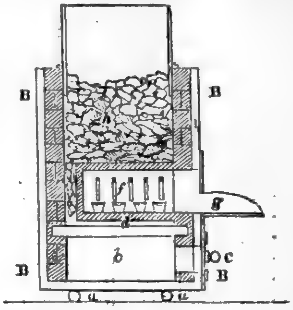
Furnace and Implements.—The cupellation-furnace and implements used for assaying in the Royal Mint and Goldsmiths' Hall, in the City of London, are the following:—

A A A A (*fig.* 1817) is a front elevation of an assay-furnace: *a a*, a view of one of the two iron rollers on which the furnace rests, and by means of which it is moved forward or backward; *b*, the ash-pit; *c c* are the ash-pit dampers, which are moved in a horizontal direction towards each other for regulating the draught of the furnace; *d*, the door, or opening, by which the cupels and assays are introduced into the muffle; *e*, a moveable funnel or chimney by which the draught of the furnace is increased.

1817

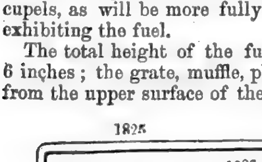


1818

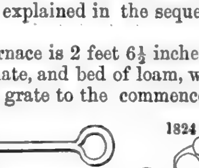


B B B B (*fig.* 1818) is a vertical section of *fig.* 1817: *a a*, end view of the rollers; *b*, the ash-pit; *c*, one of the ash-pit dampers; *d*, the grate, over which is the plate upon which the muffle rests, and which is covered with loam nearly one inch thick; *f*, the muffle in section, representing the situation of the cupels; *g*, the mouth-plate, and upon it are laid pieces of charcoal, which, during the process, are ignited, and heat the air that is allowed to pass over the cupels, as will be more fully explained in the sequel; *h*, the interior of the furnace, exhibiting the fuel.

1819

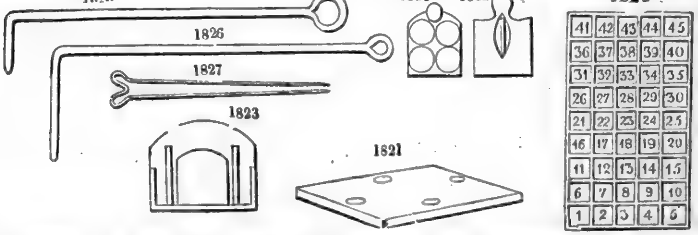


1820



The total height of the furnace is 2 feet 6½ inches; from the bottom to the grate, 6 inches; the grate, muffle, plate, and bed of loam, with which it is covered, 3 inches; from the upper surface of the grate to the commencement of the funnel, *e*, *fig.* 1817, 21½ inches; the funnel *e*, 6 inches. The square of the furnace which receives the muffle and fuel is 11¾ inches by 15 inches. The external sides of the furnace are made of plates of wrought iron, and are lined with a 2-inch fire-brick.

1825 1826 1827 1823 1821 1824 1822 1828



C C C C (*fig.* 1819) is a horizontal section of the furnace over the grate, showing the width of the mouth-piece, or plate of wrought iron, which is 6 inches, and the opening which receives the muffle-plate.

Fig. 1820 represents the muffle or pot, which is 12 inches long, 6 inches broad inside; in the clear 6¾; in height 4½ inside measure, and nearly 5½ in the clear.

Fig. 1821, the muffle-plate, which is of the same size as the bottom of the muffle.

Fig. 1822 is a representation of the sliding-door of the mouth-plate, as shown at *d*, in *fig.* 1817.

Fig. 1823, a front view of the mouth-plate or piece, *d*, *fig.* 1817.

Fig. 1824, a representation of the mode of the making, or shutting-up, with pieces of charcoal, the mouth of the furnace.

Fig. 1825, the teaser, for cleaning the grate.

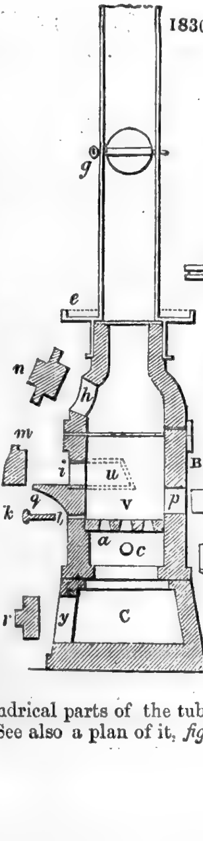
Fig. 1826, a larger teaser, which is introduced at the top of the furnace, for keeping a complete supply of charcoal around the muffle.

Fig. 1827, the tongs used for charging the assays into the cups.

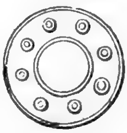
Fig. 1828 represents a board of wood used as a register, and is divided into 45 equal compartments, upon which the assays are placed previously to their being introduced into the furnace. When the operation is performed, the cupels are placed in the furnace in situations corresponding to these assays on the board. By this means all confusion is avoided, and without this regularity it would be impossible to preserve the accuracy which the delicate operations of the assayer require. In the furnace above described 45 assays can be made at one time. Of late years some modifications and improvements have been introduced in the above furnaces in the Royal Mint and other assay offices. The fuel employed is charcoal, coke, or anthracite. (See MINT.)

We now proceed to a description of a small assay-furnace invented by Messrs. Anfrye and D'Arcet, of Paris. They termed it, *le petit Fourneau à Coupelle. Fig.* 1829 represents this furnace, which is composed of a chimney or pipe of wrought iron, *a*, and of the furnace, B. It is 17½ inches high and 7¼ inches wide. The furnace is formed of three pieces: of a dome, A; the body of the furnace, B; and the ash-pit, C, which is used as the base of the furnace, *figs.* 1829 and 1830. The principal piece, or body of the furnace, B, has the form of a hollow tower, or of a hollow cylinder, flattened equally at the two opposite sides parallel to the axis, in such a manner that the horizontal section is elliptical. The foot which supports it is a hollow truncated cone, flattened in like manner upon the two opposite sides, and having consequently for its basis two ellipses of different diameters: the smallest ought to be equal to that of the furnace, so that the bottom of the latter may exactly fit it. The dome, which forms an arch above the furnace, has also its base elliptical; whilst that of the superior orifice, by which the smoke goes out, preserves the cylindrical form. The tube of wrought iron is 18 inches long, and 2½ inches in diameter; having one of its ends a little enlarged, and slightly conical, that it may be exactly fitted or jointed upon the upper part of the furnace-dome, *d* (*fig.* 1829). At the union of the conical and cylindrical parts of the tube there is placed a small gallery of iron, *e*, *figs.* 1829, 1830. (See also a plan of it, *fig.* 1831). This gallery is both ingenious

1830



1831



1832

1833

1834

1835

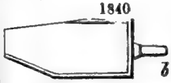
1839

1838

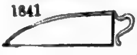
1837

1836

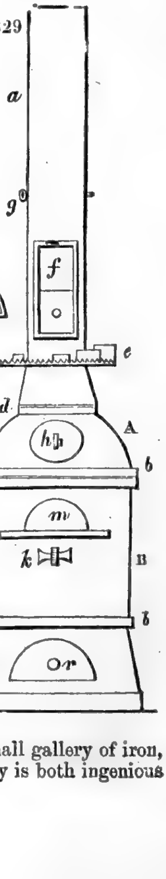
1840



1841



1829



and useful. Upon it are placed the cupels, which are thus annealed during the ordinary work of the furnace, that they may be introduced into the muffle when it is brought into its proper degree of heat. A little above this gallery is a door, *f*, by which, if thought proper, the charcoal could be introduced into the furnace; above that there is placed, at *g*, a throttle-valve, which is used for regulating the draught of the furnace at pleasure. Messrs. Anfrye and D'Arcet say, that, to give the furnace the necessary degree of heat so as to work assays of gold, the tube must be about 18 inches above the gallery for annealing or heating the cupels. The circular opening in the dome, *h* (*fig.* 1829, and as seen in section *fig.* 1830), is used to introduce the charcoal into the furnace: it is also used to inspect the interior of the furnace, and to arrange the charcoal round the muffle. This opening is kept shut during the working of the furnace, with the mouth-piece, of which the face is seen at *n*, *fig.* 1830.

The section of the furnace, *fig.* 1830, presents several openings, the principal of which is that of the muffle; it is placed at *i*; it is shut with the semicircular door *m*, *fig.* 1829, and seen in the section *m*, *fig.* 1830. In front of this opening, is the table or shelf upon which the door of the muffle is made to advance or recede. The letter *q*, *fig.* 1830, shows the face, side, and cross-section of the shelf, which makes part of the furnace. Immediately under the shelf is a horizontal slit, *l*, which is pierced at the level of the upper part of the grate, and used for the introduction of a slender rod of iron, that the grate may be easily kept clean. This opening is shut at pleasure, by the wedge represented at *k*, *figs.* 1829 and 1830.

Upon the back of the furnace is a horizontal slit, *p*, *fig.* 1830, which supports the fire-brick, *s*, and upon which the end of the muffle, if necessary, may rest; *u*, *fig.* 1830, is the opening in the furnace where the muffle is placed.

The plan of the grate of the furnace is an ellipse: *fig.* 1832 is a horizontal view of it. The dimensions of that ellipsis determine the general form of the furnace, and thickness of the grate. To give strength and solidity to the grate, it is encircled by a bar or hoop of iron. There is a groove in which the hoop of iron is fixed. The holes of the grate are truncated cones, having the greater base below, that the ashes may more easily fall into the ash-pit. The letter *v*, *fig.* 1830, shows the form of these holes. The grate is supported by a small bank or shelf, making part of the furnace, as seen at *a*, *fig.* 1830.

The ash-pit, c, has an opening, *y*, in front, *fig.* 1830; and is shut when necessary by the mouth-piece, *r*, *figs.* 1829 and 1830.

To give strength and solidity to the furnace, it is bound with hoops of iron, at *b b b b*, *fig.* 1829.

Figs. 1833, 1834, 1835, are views of the muffle.

Fig. 1836 is a view of a crucible for annealing gold.

Figs. 1837, 1838, 1839, are cupels of various sizes, to be used in the furnace. They are the same as those used by assayers in their ordinary furnaces.

Figs. 1840 and 1841 are views of the hand-shovels, used for filling the furnace with charcoal; they should be made of such size and form as to fit the opening *h*, in *figs.* 1829 and 1830.

The smaller pincers or tongs, by which the assays are charged into the cupels, and by which the latter are withdrawn from the furnace, as well as the teaser for cleansing the grate of the furnace, are similar to those used at the British Mint. (See MINT.)

Cupel-mould; Cupels.—The cupels used in the assay process are made of the ashes of burnt bones (phosphate of lime). The cupels are formed in a cupel-mould made of cast steel, very nicely turned, by which means they are easily freed from the mould when struck. The bone-ash is used moistened with a quantity of water, sufficient to make the particles adhere firmly together. The circular mould is filled, and pressed level with its surface; after which, a pestle or plug, having its end nicely turned, of a convex shape, and of a size equal to the degree of concavity wished to be made in the cupel for the reception of the assay, is placed upon the ashes in the mould, and struck with a mallet until the cupel is properly formed. These cupels are allowed to dry in the air for some time before they are used.

The assay by cupellation may be conducted as follows:—

We begin this assay process by weighing, in a delicate balance, a certain weight of the metallic alloy; a gramme (= 15·432 gr.) is usually taken in France, and 10 or 12 grains in this country. The weight is wrapped up in a slip of lead-foil or paper, should it consist of several fragments; and there is added to it the proportion of lead suitable to the quality of alloy to be assayed; there being less lead, the finer the silver is presumed to be. Those who are much in the habit of cupellation can make good guesses in this way. If too much lead be used for the proportion of baser metal present, a portion of the silver is wasted; but if too little, then the whole of the copper is not carried off, and the button of fine silver remains more or less impure. The lead must be, in all cases, as free as practicable from silver; otherwise errors of the most serious kind would be occasioned in the assays.

The assay is then placed upon a cupel which has been previously heated to the proper temperature in the muffle, and the door closed. Fusion immediately occurs, and the cupellation begins when the uncovering, or removal of the black skin of oxide of lead takes place. The oxidation of the lead proceeds rapidly, and the spots of oxide formed on the surface are rapidly absorbed by the cupel. Near the completion of the assay the oxide forms thin films or bands; and when the surface of the silver becomes bright and immoveable, as the brightening occurs, the cupellation is finished. The cupel is now allowed to remain in the muffle until the temperature is diminished and the silver is solid. It is now removed from the muffle, and when cold the button of silver is detached from the cupel by a pair of pliers squeezed or hammered on the side, the under surface cleaned by means of a hard brush, and finally weighed. An assay is thought to be good when the bead is of a round form, if its upper surface is brilliant and crystalline, its lower surface granular and dead white, and if it separates readily from the cupel. When copper is present the oxide of copper produced forms a fusible compound with the oxide of lead and passes into the cupel. The proportion of lead added varies with the amount of copper present in the alloy operated on.

Quantity of Lead to be employed for Cupellation of Alloys of Copper and Silver
(M. D'Arcet).

Alloy		Lead for 1 of alloy	Ratio of the copper to the lead
Silver	Copper		
1000	0	$\frac{3}{10}$	0
950	50	3	1 : 70
900	100	7	1 : 60
800	200	10	1 : 50
700	300	12	1 : 40
600	400	14	1 : 35
500	500	16 or 17	1 : 32
400	600	16 — 17	1 : 26·7
300	700	16 — 17	1 : 22·9
200	800	16 — 17	1 : 20
100	900	16 — 17	1 : 17·8
0	1000	16 — 17	1 : 16

Bismuth may be used as a substitute for lead in cupellation; two parts of it being nearly equivalent to three of lead. But its higher price prevents its introduction among assayers.

During the process of cupellation, a portion of the silver is absorbed by the cupel, varying in amount according to the temperature and the quantity of lead employed. This loss is estimated and added on to the weight of the button of silver obtained. The results are returned on 1,000 parts or on the pound troy. It is also customary to report the assays in relation to standard. For example, English standard silver contains 925 parts of silver in 1,000 of alloy. If the result obtained was 920, it would be reported 5 W., or 5 parts in 1,000 worse than standard, and 930 would be reported 5 B., or 5 parts better than standard.

An assay may prove defective for several reasons. Sometimes the button or bead sends forth crystalline vegetations on its surface with such force as to make one suppose a portion of the silver may be thrown out of the cupel, technically called '*spitting*.' When the surface of the bead is dull and flat, the assay is considered to have been too hot, and it indicates a loss of silver in fumes. When the tint of the bead is not uniform, when its inferior surface is bubbly, when yellow scales of oxide of lead remain on the bottom of the cupel, and the bead adheres strongly to it,—by these signs it is judged that the assay has been too cold, and that the silver retains some lead. After the lead is put into the cupel, it gets immediately covered with a coat of oxide, which resists the admission of the silver to be assayed into the melted metal; so that the alloy cannot form. When a bit of silver is laid on a lead-bath in this predicament, we see it swim about a long time without dissolving. In order to avoid this result, the silver is wrapped up in a bit of paper; and the carburetted hydrogen generated by its combustion reduces the film of the lead oxide, gives the bath immediately a bright metallic lustre, and enables the two metals readily to combine. As the heat rises, the oxide of lead flows round about over the surface, till it is absorbed by the cupel. When the lead is wasted to a certain degree, a very thin film of it only remains on the silver, which causes the iridescent appearance like the colours of soap-bubbles: a phenomenon called, by the old chemists, fulguration.

When the cupel cools in the progress of the assay, the oxidation of the lead ceases; and, instead of a very liquid vitreous oxide, an imperfectly-melted oxide is formed, which the cupel cannot absorb. To correct a cold assay, the temperature of the furnace ought to be raised, and pieces of paper put into the cupel, till the oxide of lead which adheres to it be reduced. On keeping up the heat, the assay will resume its ordinary train. Pure silver is more liable to vegetate. Some traces of copper destroy this property, which is obviously due to the oxygen which the silver can absorb while it is in fusion, and which is disengaged the moment it solidifies. An excess of lead, by removing all the copper at an early stage, tends to cause the vegetation. The brightening is caused by the heat evolved when the button passes from the liquid to the solid state. Many other substances present the same phenomenon. In the above operation it is necessary to employ lead which is very pure, or at least free from silver. This is called *poor lead.* The lead reduced from Pattinson's 'oxychloride' is very free from silver; the lead reduced from the litharge of commerce usually contains 10 dwts. or more of silver per ton.

2. *Wet Methods.* (*a.*) *By means of a Standard Solution of Salt or Chloride of Sodium.*—The process by the humid way, recommended at the Royal Mint in 1829, and exhibited as to its principles before the Right Honourable John Herries, then Master, in 1830, has all the precision and certainty we could wish. It is founded on the well-known property which silver has, when dissolved in nitric acid, to be precipitated as an insoluble chloride of silver by a solution of salt or by muriatic acid; but, instead of determining the weight of the chloride of silver, we take the quantity of the solution of salt which has been necessary for the precipitation of the silver. To put the process in execution, a liquor is prepared composed of water and salt in such proportions that 1,000 measures of this liquor may precipitate completely 10 grains of silver, perfectly pure or of the standard 1,000, previously dissolved in nitric acid. The liquor thus prepared gives, immediately, the true standard of any alloy whatever, of silver and copper, by the quantity of which it may be necessary to precipitate the silver in a known weight of this alloy.

The process by the humid way is, so to speak, independent of the operator, the manipulations being very easy; and the term of the operation is very distinctly announced by the absence of any sensible turbidity on the addition of salt to the silver solution, while there remains in it one quarter of a thousandth of metal. The process is not tedious, and in experienced hands it may rival the cupel in rapidity; it has the advantage over the cupel of being more within the reach of ordinary operators, and of not requiring a long apprenticeship. It is particularly useful to such assayers as have only a few assays to make daily, as it will cost them very little time and expense.

By agitating briskly, during two minutes, the liquid rendered milky by the precipitation of the chloride of silver, it may be sufficiently clarified to enable us to appreciate, after a few moments of repose, the disturbance that can be produced in it by the addition of 1000th of a grain of silver. The presence of lead and copper, or any other metal, except mercury, has no perceptible influence on the quantity of salt necessary to precipitate the silver; that is to say, the same quantity of silver, pure or alloyed, requires for its precipitation a constant quantity of the solution of salt.

Supposing that we operate upon a gramme of pure silver, the solution of salt ought to be such that 100 cubic centimeters may precipitate exactly the whole of the silver. The standard of an alloy is given by the number of thousandths of solution of salt necessary to precipitate the silver contained in a gramme of alloy.

When any mercury is accidentally present, which is however, a rare occurrence, it is made obvious by the precipitated chloride remaining white when exposed to daylight; whereas, when there is no mercury present, it becomes speedily first grey and then purple. Silver so contaminated must be strongly ignited before being assayed, and the loss of weight noted; or a cupel assay may be had recourse to.

The following is a description of the process and apparatus as first introduced by Gay-Lussac:—

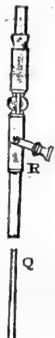
Preparation of the Normal Solution of Salt when it is measured by Weight.—Supposing the salt pure as well as the water, we have only to take these two bodies in the proportion of 0·5437 k. of salt to 99·4573 k. of water, to have 100 k. of solution, of which 100 grammes will precipitate exactly one gramme of silver. But instead of pure salt, which is to be procured with difficulty, and which besides may be altered readily by absorbing the humidity of the air, a concentrated solution of the salt of commerce is to be preferred, of which a large quantity may be prepared at a time to be kept in reserve for use, as it is wanted.

Preparation of the Normal Solution of Salt when measured by Volume.—The measure by weight has the advantage of being independent of temperature, of having the same degree of precision as the balance, and of not standing in need of correction. The measure by volume has not all these advantages; but, by giving it sufficient precision, it is more rapid. This normal solution is so made, that a volume equal to that of 100 grammes of water, or 100 cubic centimeters, at a determinate temperature, may precipitate exactly one gramme of silver. The solution may be kept at a constant temperature, and in this case the assay stands in no want of correction; or if its temperature be variable, the assay must be corrected according to its influence. These two circumstances make no change in the principle of the process, but they are sufficiently important to occasion some modifications in the apparatus.

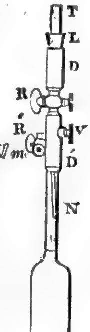
We readily obtain a volume of 100 cubic centimeters by means of a *pipette, fig.* 1841, so gauged, that when filled with water up to the mark *a b*, and well dried at its point, it will run out, at a continuous efflux, 100 grammes of water at the temperature of 15° C. (59° F.) We say purposely at one efflux, because after the cessation of the jet, the pipette may still furnish two or three drops of liquid, which must not be counted or reckoned upon. The weight of the volume of the normal solution, taken in this manner with suitable precautions, will be uniform from one extreme to another, upon two centimeters and a half, at most, or to a quarter of a thousandth, and the difference from the mean will be obviously twice less, or one half. Let us indicate the most simple manner of taking a measure of the normal solution of salt.

After having immersed the beak, *c*, of the pipette in the solution, we apply suction, by the mouth, to the upper orifice, and thereby raise the liquid to *d*, above the circular line *a b*. We next apply neatly the forefinger of one hand to this orifice, remove the pipette from the liquid, and seize it as represented in *fig.* 1842. The mark *a b* being placed at the level of the eye, we make the surface of the solution become exactly a tangent to the plane *a b*. At the instant it becomes a tangent, we leave the beak, *c*, of the pipette open, by taking away the finger that had been applied to it, and without changing anything else in the position of the hands, we empty it into the bottle which should receive the solution, taking care to remove it whenever the efflux has run out.

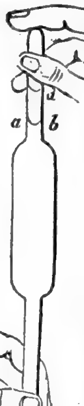
1844



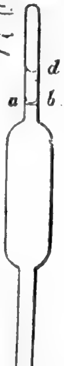
1843



1842



1841



If, after filling the pipette by suction, anyone should find a difficulty in applying the forefinger fast enough to the upper orifice without letting the liquid run down below the mark *a b*, he should remove the pipette from the solution with its top still closed with his tongue, then apply the middle finger of one of his hands to the lower orifice; after which he may withdraw his tongue, and apply the forefinger of the other hand to the orifice previously wiped. This method of obtaining a measure of normal solution of sea-salt is very simple, and requires no complex apparatus; but we shall indicate another manipulation still easier, and much more exact.

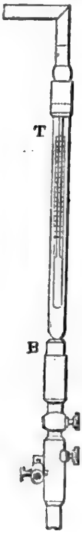
In this new process the pipette is filled from the top like a bottle, instead of being filled by suction, and it is moreover fixed. *Fig.* 1843 represents the apparatus. D and D' are two sockets, separated by a stopcock R. The upper one, tapped interiorly, receives by means of a cork stopper, L, the tube T, which admits the solution of sea-salt. The lower socket is cemented on to the pipette; it bears a small air-cock R', and a screw-plug V, which regulates a minute opening intended to let the air enter very slowly into the pipette. Below the stopcock R', a silver tube, N, of narrow diameter, soldered to the socket, leads the solution into the pipette, by allowing the air, which it displaces, to escape by the stopcock, R'. The screw-plug, with the milled head, V, replaces the ordinary screw by which the key of the stopcock may be made to press, with more or less force, upon its conical seat.

Fig. 1844 represents a side view of the apparatus just described. We here remark an air-cock R, and an opening *m*. At the extremity Q, of the same figure, the conical pipe T enters with friction. It is by this pipe that the air is sucked into the pipette, when it is to be filled from its beak.

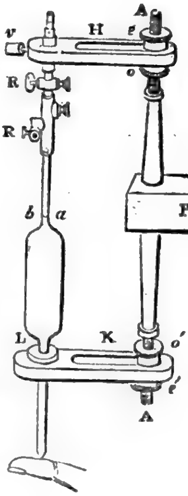
The pipette is supported by two horizontal arms H K (*fig.* 1845) moveable about a common axis, A A, and capable of being drawn out or shortened by the aid of two longitudinal slits. They are fixed steadily by two screw-nuts, *e e′*, and their distance may be varied by means of round bits of wood or cork interposed, or even by opposite screw-nuts, *o o′*. The upper arm H is pierced with a hole, in which is fixed, by the pressure of a wooden screw *v*, the socket of the pipette. The corresponding hole of the lower arm is larger; and the beak of the pipette is supported in it by a cork stopper, L. The apparatus is fixed by its tail-piece P, by means of a screw to the corner of a wall, or any other prop.

The manner of filling the pipette is very simple. We begin by applying the forefinger of the left hand to the lower aperture, *c*; we then open the two stopcocks R and R′. Whenever the liquor approaches the neck of the pipette, we must temper its influx, and when it has arrived at some millimeters above the mark *a b*, we close the two stopcocks, and remove our forefinger. We have now nothing more to do than to regulate the pipette; for which purpose the liquid must touch the line *a b*, and must simply adhere externally to the beak of the pipette.

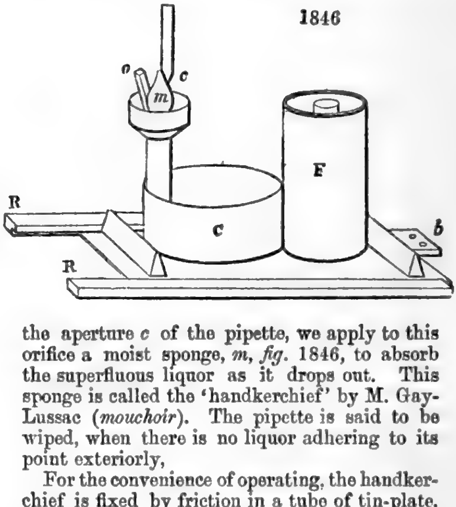
1847



1845



1846



This last circumstance is easily adjusted. After taking away the finger which closed the aperture *c* of the pipette, we apply to this orifice a moist sponge, *m*, *fig.* 1846, to absorb the superfluous liquor as it drops out. This sponge is called the 'handkerchief' by M. Gay-Lussac (*mouchoir*). The pipette is said to be wiped, when there is no liquor adhering to its point exteriorly,

For the convenience of operating, the handkerchief is fixed by friction in a tube of tin-plate, terminated by a cup, open at bottom to let the droppings flow off into the cistern C, to which the tube is soldered. It may be easily removed for the purpose of washing it; and, if necessary, a little wedge of wood, *o*, can raise it towards the pipette.

To complete the adjustment of the pipette, the liquid must be made merely to descend to the mark *a*, *b*. With this view, and whilst the handkerchief is applied to the beak of the pipette, the air must be allowed to enter very slowly, by unscrewing the plug *v*, *fig.* 1843; and at the moment of the contact, the handkerchief must be removed, and the bottle F, destined to receive the solution, must be placed below the orifice of the pipette, *fig.* 1846. As the motion must be made rapidly, and without hesitation, the bottle is placed in a cylinder of tin-plate, of a diameter somewhat greater, and forming one body with the cistern and the handkerchief. The whole of this apparatus has for a basis a plate of tinned-iron, moveable between the wooden rollers R R, one of which bears a groove, under which the edge of the plate slips. Its traverses are fixed by two abutments, *b b*, placed so that when it is stopped by one of them, the beak of the pipette corresponds to the centre of the neck of the bottle, or is a tangent to the handkerchief. This arrangement, very convenient for wiping the pipette, and emptying it, gives the apparatus sufficient solidity, and allows of its being taken away, and replaced without deranging anything. It is obvious that it is of advantage, when once the entry of the air into the pipette has been regulated by the screw V, to leave it constantly open, because the motion from the handkerchief to the bottle is performed with sufficient rapidity to prevent a drop of the solution from collecting and falling down.

Temperature of the Solution.—After having described the manner of measuring by volume the normal solution of the salt, we shall indicate the most convenient means of taking the temperature. The thermometer is placed in a tube of glass, T, *fig.* 1847, which the solution traverses to arrive at the pipette. It is suspended in it by a piece of cork, grooved on the four sides to afford passage to the liquid. The scale is engraved upon the tube itself, and is repeated at the opposite side, to fix the eye by the coincidence of this double division at the level of the thermometric column. The tube is joined below to another narrower one, through which it is attached by means of a cork stopper B, in the socket of the stopcock of the pipette. At its upper part it is cemented into a brass socket, screw-tapped in the inside, which is connected in its turn by a cock, with the extremity, also tapped, of the tube above T, belonging to the reservoir of the normal solution. The corks employed here as connecting links between the parts of the apparatus, give them a certain flexibility, and allow of their being dismounted and remounted in a very short time; but it is indispensable to make them be traversed by a hollow tube of glass or metal, which will hinder them from being crushed by the pressure they are exposed to. If the precaution be taken to grease them with a little suet, and to fill their pores, they will suffer no leakage.

For the preservation of the normal solution of salt, M. Gay-Lussac uses a cylindrical vessel or drum of copper, of a capacity of about 110 litres, having its inside covered with a resin-and-wax cement. If the drum contains 110 litres, we should only put 105 into it, in order that sufficient space may be left for agitating the liquor without throwing it out. According to the principle that 100 cubic centimeters, or $\frac{1}{10}$th of a litre of the solution should contain enough of salt to precipitate a gramme of pure silver; and, admitting moreover, 13·516 for the equivalent of silver, and 7·335 for that of salt, we shall find the quantity of pure salt that should be dissolved in the 105 litres of water, and which corresponds to $105 \times 10 = 1050$ grammes of silver, to be, by the following proportion:—

$$13{\cdot}516 : 7{\cdot}335 :: 1050 \text{ grammes} : x = 569{\cdot}83 \text{ grammes.}$$

And as the solution of the salt of commerce, formerly mentioned, contains approximatively 250 grammes per kilogramme, we must make 2279·3 grammes of this solution to have 569·83 grammes of salt. The mixture being perfectly made, the tubes and the pipette must be several times washed by running the solution through them, and putting it into the drum. The standard of the solution must be determined after it has been well agitated, supposing the temperature to remain uniform.

To arrive more conveniently at this result, we begin by preparing two decimal solutions; one of silver, and another of salt.

The decimal solution of silver is obtained by dissolving 1 gramme of silver in nitric acid, and diluting the solution with water till its volume becomes a litre.

The decimal solution of salt may be obtained by dissolving 0·543 gramme of pure salt in water, so that the solution shall occupy a litre; but we shall prepare it even with the normal solution which we wish to test, by mixing a measure of it with 9 measures of water; it being understood that this solution is not rigorously equivalent to that of silver, and that it will become so only when the normal solution employed for its preparation shall be finally of the true standard. Lastly, we prepare beforehand several stoppered bottles, in each of which we dissolve 1 gramme of silver in 8 or 10 grammes of nitric acid. For brevity's sake, we shall call these 'tests.'

Now, to investigate the standard of the normal solution, we must transfer a pipette of it into one of these test-bottles; and we must agitate the liquors briskly to clarify them. After some instants of repose, we pour in 2 thousandths of the decimal solution of salt, which we suppose will produce a precipitate. The normal liquor is consequently too feeble; and we should expect this, since the salt employed was not perfectly pure. We agitate and add 2 fresh thousandths, which will also produce a precipitate. We continue thus, by successive additions of 2 thousandths till the last produces no precipitation. Suppose that we have added 16 thousandths: the last two should not be reckoned, as they produced no precipitate; the preceding two were necessary, but only in part; that is to say, the useful thousandths added are above 12 and below 14, or otherwise they are on an average equal to 13.

Thus, in the condition of the normal solution, we require 1,013 parts of it to precipitate 1 gramme of silver, while we should require only 1,000. We shall find the quantity of concentrated solution of salt that we should add, by noting that the quantity of solution of salt, at first employed, viz. 2279·3 grammes, produced a standard of only 987 thousandths $= 1000 - 13$; and by using the following proportion:

$$987 : 2279{\cdot}3 :: 13 : x = 30{\cdot}02 \text{ grammes.}$$

This quantity of the strong solution of salt, mixed with the normal solution in the drum, will correct its standard, and we shall see now by how much.

After having washed the tubes and the pipette with the new solution, we must repeat the experiment upon a fresh gramme of silver. We shall find, for example, in proceeding only by a thousandth at a time, that the first causes a precipitate, but not the second. The standard of the solution is still too weak, and is comprised between 1000 and 1001; that is to say, it may be equal to 1000½, but we must make a closer approximation.

We pour into the test-bottle 2 thousandths of the decimal solution of silver, which will destroy 2 thousandths of salt, and the operation will have retrograded by 2 thousandths; that is to say, it will be brought back to the point at which it was first of all. If, after having cleared up the liquor, we add half a thousandth of the decimal solution, there will necessarily be a precipitate, as we knew beforehand, but a second will cause no turbidity. The standard of the normal liquor will be consequently comprehended between 1000 and 1000½, or equal to 1000¼.

We should rest content with this standard; but if we wish to correct it, we may remark that the two quantities of solution of salt added, viz. 2279·3 gr. + 30·02 gr. = 2309·32 gr., have produced only 999·75 thousandths, and that we must add a new quantity of it corresponding to ¼ of a thousandth. We make, therefore, the proportion

$$999{\cdot}75 : 2309{\cdot}32 :: 0{\cdot}25 : x.$$

But since the first term differs very little from 1000, we may content ourselves to have x by taking the $\frac{0{\cdot}25}{1000}$ of 2309·32, and we shall find 0·577 gr. for the quantity of solution of salt to be added to the normal solution.

It is not convenient to take exactly so small a quantity of solution of salt by the balance, but we shall succeed easily by the following process. We weigh 50 grammes of this solution, and we dilute it with water, so that it occupies exactly half a litre, or 500 centimeters cube. A pipette of this solution, one centimeter cube in volume, will give a decigramme of the primitive solution, and as such a small pipette is divided into twenty drops, each drop, for example, will present 5 milligrammes of the solution. We should arrive at quantities smaller still by diluting the solution with a proper quantity of water; but greater precision would be entirely needless.

The testing of the normal liquor just described is, in reality, less tedious than might be supposed. It deserves also to be remarked, that liquor has been prepared for more than 1,000 assays; and that, in preparing a fresh quantity, we shall obtain directly its true standard, or nearly so, if we bear in mind the quantities of water and solution of salt which have been employed.

Correction of the Standard of the Normal Solution of Salt, when the Temperature changes.—We have supposed, in determining the standard of the normal solution of salt, that the temperature remained uniform. The assays made in such circumstances have no need of correction; but if the temperature should change, the same measure of the solution will not contain the same quantity of salt. Supposing that we have tested the solution of the salt at the temperature of 15° C.; if, at the time of making the experiment, the temperature is 18° C., for example, the solution will be too weak on account of its expansion, and the pipette will contain less of it by weight; if, on the contrary, the temperature has fallen to 12°, the solution will be thereby concentrated, and will prove too strong. It is therefore proper to determine the correction necessary to be made for any variation of temperature.

To ascertain this point, the temperature of the solution of salt was made successively, to be 0, 5°, 10°, 15°, 20°, 25°, and 30° C., and three pipettes of the solution were weighed exactly at each of these temperatures. The third of these weighings gave the mean weight of a pipette. The corresponding weights of a pipette of the solution were afterwards graphically interpolated from degree to degree. These weights form the second column of the following Table. They enable us to correct any temperature between 0° and 30° C. (32° and 86° F.) when the solution of salt has been prepared in the same limits.

Let us suppose, for example, that the solution has been made standard at 15°, and that at the time of using it, the temperature has become 18°. We see by the second column of the Table, that a weight of a measure of the solution is 100·099 gr. at 15°, and 100·065 at 18°; the difference, 0·034 gr., is the quantity of solution less which has been really taken; and of course we must add it to the normal measure, in order to make it equal to one thousand *millièmes.* If the temperature of the solution had fallen to 10° the difference of the weight of a measure from 10° to 15° would be 0·019 gr., which we must, on the contrary, deduct from the measure, since it had been taken too large. These differences of weight of a measure of solution at 15°, from that of a measure at any other temperature, form the column 15° of the table where they are expressed in thousandths; they are inscribed on the same horizontal lines as to the temperatures to which each of them relates with the sign + *plus,* when they must be added, and with the sign − *minus,* when they must be subtracted.

Table of Correction for the Variations in the Temperature of the Normal System of the Salt.

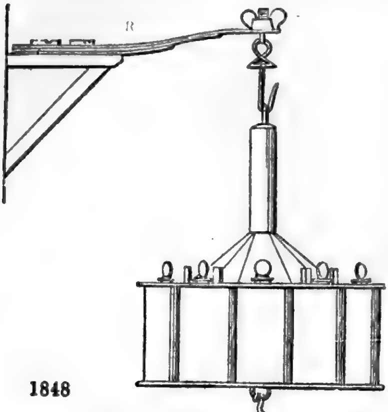
Temperature	Weight	5°	10°	15°	20°	25°	30°
degrees	gram.	mill.	mill.	mill.	mill.	mill.	mill.
4	100,109	0·0	−0·1	+0·1	+0·7	+1·7	+2·7
5	100,113	0·0	−0·1	+0·1	+0·7	+1·7	+2·8
6	100,115	0·0	0·0	+0·2	+0·8	+1·7	+2·8
7	100,118	+0·1	0·0	+0·2	+0·8	+1·7	+2·8
8	100,120	+0·1	0·0	+0·2	+0·8	+1·8	+2·8
9	100,120	+0·1	0·0	+0·2	+0·8	+1·8	+2·8
10	100,118	+0·1	0·0	+0·2	+0·8	+1·7	+2·8
11	100,116	0·0	0·0	+0·2	+0·8	+1·7	+2·8
12	100,114	0·0	0·0	+0·2	+0·8	+1·7	+2·8
13	100,110	0·0	−0·1	+0·1	+0·7	+1·7	+2·7
14	100,106	−0·1	−0·1	+0·1	+0·7	+1·6	+2·7
15	100,099	−0·1	−0·2	−0·0	+0·6	+1·6	+2·6
16	100,090	−0·2	−0·3	−0·1	+0·5	+1·5	+2·5
17	100,078	−0·4	−0·4	−0·2	+0·4	+1·3	+2·4
18	100,065	−0·5	−0·5	−0·3	+0·3	+1·2	+2·3
19	100,053	−0·6	−0·7	−0·5	+0·1	+1·1	+2·2
20	100,039	−0·7	−0·8	−0·6	0·0	+1·0	+2·0
21	100,021	−0·9	−1·0	−0·8	−0·2	+0·8	+1·9
22	100,001	−1·1	−1·2	−1·0	−0·4	+0·6	+1·7
23	99,983	−1·3	−1·4	−1·2	−0·6	+0·4	+1·5
24	99,964	−1·5	−1·5	−1·4	−0·8	+0·2	+1·3
25	99,944	−1·7	−1·7	−1·6	−1·0	0·0	+1·1
26	99,924	−1·9	−1·9	−1·8	−1·2	−0·2	+0·9
27	99,902	−2·1	−2·2	−2·0	−1·4	−0·4	+0·7
28	99,879	−2·3	−2·4	−2·2	−1·6	−1·6	+0·7
29	99,858	−2·6	−2·6	−2·4	−1·8	−0·9	+0·2
30	29,836	−2·8	−2·8	−2·6	−2·0	−1·1	0·0

The columns 5°, 10°, 20°, 25°, 35°, have been calculated in the same manner for the cases in which the normal solution may have been graduated to each of these temperatures. Thus, to calculate the column 10°, the number 100·118 has been taken in the column of weights for a term of departure, and its difference from all the numbers of the same column has been sought.

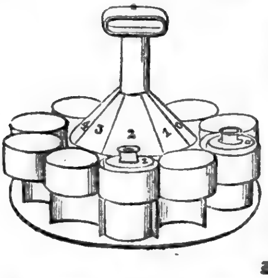
Several expedients have been employed to facilitate and abridge the manipulations. In the first place, the bottles for testing or assaying the specimens of silver should all be of the same height and of the same diameter. They should be numbered at their top, as well as on their stoppers, in the order 1, 2, 3, &c. They may be ranged successively in tens; the stoppers of the same series being placed on a support in their proper order. Each two bottles should, in their turn, be placed in a japanned tin case (*fig.* 1848) with ten compartments, duly numbered. These compartments are cut out anteriorly to about half their height, to allow the bottoms of the bottles to be seen. When each bottle has received its portion of alloy, through a wide-beaked funnel, there must be poured into it about 10 grammes of nitric acid, of specific gravity 1·28, with a pipette, containing that quantity; it is then exposed to the heat of a water-bath, in order to facilitate the solution of the alloy. The water-bath is an oblong vessel made of tin-plate, intended to receive the bottles. It has a moveable double bottom, pierced with small holes for the purpose of preventing the bottles being broken, as it insulates them from the bottom, to which the heat is applied. The solution is rapid; and, since it emits nitrous vapours in abundance, it ought to be carried on under a chimney.

The Agitator.—Fig. 1849 gives a sufficiently exact idea of it, and may dispense with a lengthened description. It has ten cylindrical compartments, numbered from 1 to 10. The bottles, after the solution of the alloy, are arranged in it in the order of their numbers. The agitator is then placed within reach of the pipette intended to measure out the normal solution of salt, and a pipette full of this solution is put into each phial. Each is then closed with its glass-stopper, previously dipped in pure water. They are fixed in the cells of the agitator by springs. The agitator is then suspended to a spring R, and, seizing it with both hands, the operator gives an alternating rapid movement, which agitates the solution, and makes it, in less than a minute, as limpid as water. This movement is sometimes promoted by a spiral spring, B, fixed to the agitator and the ground; but this is seldom made use of, because it is convenient to be able to transport the agitator from one place to another. When the agitation is finished, the catches are released, and the bottles are placed in order upon a table furnished with round cells destined to receive them, and to screen them. When we place the bottles upon this table, we must give them a brisk circular motion to collect the chloride of silver scattered round their sides; we must lift out their stoppers, and suspend them in wire rings, or pincers. We next pour a thousandth of the decimal solution into each bottle; and before this operation is terminated, there is formed in the first bottle, when there *should be* a precipitate, a nebulous stratum, very well marked, of about a centimeter in thickness. At the back of the table there is a black board, divided into compartments, numbered from 1 to 10, upon each of which we mark, with chalk, the thousandths of the decimal liquor put into the corresponding bottle. The thousandths of salt, which indicate an augmentation of standard, are preceded by the sign +, and the thousandths of nitrate of silver by the sign −. When the assays are finished, the liquor of each bottle is to be poured into a large vessel in which a slight excess of salt is kept; and when it is full, the supernatant clear liquid must be run off with a syphon.

1849



1848



The chloride of silver may be reduced without any perceptible loss. After having washed it well, we immerse pieces of zinc in it, and add sulphuric acid in sufficient quantity to keep up a feeble disengagement of hydrogen gas. The mass must not be touched. In a few days the silver is completely reduced. This is easily recognised by the colour and nature of the product; or by treating a small quantity of it with water of ammonia, we shall see whether there be any chloride unreduced, for it will be dissolved by the ammonia, and will again appear upon saturating the ammonia with an acid. The chlorine remains associated with the zinc in a state of solution. The first washings of the reduced silver must be made with an acidulous water, to dissolve the oxides which may have been formed, and the other washings with common water. After decanting the water of the last washing, we dry the mass, and add to it a little powdered borax. It must now be fused. The silver being in a bulky powder is to be put in successive portions into a crucible as it sinks down. The heat should be at first moderate; but towards the end of the operation, it must be pretty strong, to bring into complete fusion the silver and the scoriæ, and to effect their complete separation. In case it should be supposed that the whole of the silver had not been reduced by the zinc, a little carbonate of potash should be added to the borax. The silver may also be reduced by exposing the chloride to a strong heat, in contact with chalk and charcoal.

The following remarks by M. Gay-Lussac, the author of the above method, upon the effect of a little mercury in the humid assay, are important:—

It is well known that chloride of silver blackens the more readily when it is exposed to an intense light, and that even in the diffused light of a room it becomes soon sensibly coloured. If it contains 4 to 5 thousandths of mercury, it does not blacken; it remains of a dead white; with 3 thousandths of mercury, there is no marked discolouring in diffused light; with 2 thousandths it is slight; with 1 it is much more marked, but still it is much less intense than with pure chloride. With half a thousandth of mercury the difference of colour is not remarkable, and is perceived only in a very moderate light. But when the quantity of mercury is so small that it cannot be detected by the difference of colour in the chloride of silver, it may be rendered quite evident by a very simple process of concentration. Dissolve one gramme of the silver supposed to contain a quarter of a thousandth of mercury, and let only a quarter of it be precipitated, by adding a quarter of the common salt necessary to precipitate it entirely. In thus operating, the quarter thousaudth of mercury is concentrated in a quantity of chloride of silver four times smaller: it is as if the silver having been entirely precipitated, four times as much mercury, equal to 2 thousandths, have been precipitated with it. On taking two grammes of silver, and precipitating only a quarter by common salt, the precipitate would be, with respect to the chloride of silver, as if it amounted to 4 thousandths. By this process, which occupies only five minutes because exact weighing is not necessary, one tenth of a thousandth of mercury may be detected in silver. It is not useless to observe that, in making these experiments, the most exact manner of introducing small quantities of mercury into a solution of silver, is to weigh a minute globule of mercury, and to dissolve it in nitric acid, diluting the solution so that it may contain as many cubic centimeters as the globule weighs of centigrammes. Each cubic centimeter, taken by means of a pipette, will contain one milligramme of mercury. If the ingot of silver to be assayed be found to contain a greater quantity of mercury—1 thousandth, for example—the humid process ought, in this case, either to be given up or to be compared with cupellation. When the silver contains mercury, the solution from which the mixed chlorides are precipitated does not really become clear. Silver containing mercury, put into a small crucible, and mixed with lamp-black, to prevent the volatilisation of the silver, was heated for three-quarters of an hour in a muffle, but the silver increased sensibly in weight. This process for separating the mercury, therefore, failed. It is to be observed, that mercury is the only metal which has thus the power of disturbing analysis by the humid way. The error caused by the presence of mercury may be avoided by the addition of a small quantity of acetate of soda to the solution of the silver in nitric acid, previous to the addition of the chloride of sodium, as this salt prevents the precipitation of the mercury.

Since the above process was first introduced by Gay-Lussac, several modifications in the form of apparatus and other details have been introduced; but the principles upon which the method is worked are essentially the same. The normal solution of salt is preserved in a vessel of glass or stoneware, instead of metal. The use of metal tubes is dispensed with. Various modes of filling the pipettes from below or otherwise are in use. Instead of the thermometer placed within the tube to indicate the temperature of the salt-solution, the standard is verified once a day or oftener if necessary by check assays. The assay of silver, or silver alloys by a standard solution of salt may be conducted as follows:—Ten grs. or more of the metal according to circumstances, is weighed out, transferred to the bottle, dilute nitric acid added and solution effected by placing the bottle in a water-bath. The red fumes are expelled, and the solution diluted with water. The bottle is now placed under the lower end of the pipette, 1000 grs. of the normal solution of salt (equal to ten grs. of silver) run in, and the contents briskly shaken until clear. Ten grs. of the decimal solution of salt (1000 grs. of which are equal to 1 gr. of silver) is now added from a pipette and, as precipitate forms, the solution is again shaken until clear. This process is repeated until the last 10 grs. added, does not produce any precipitate. As the last 10 grs. of decimal solution added does not give any precipitate, it proves that it is in excess; it is therefore, deducted from the total quantity used, and also the half, say of the previous 10 grs. added, as it is obvious that the previous 10 grs. added were not sufficient to precipitate the whole of the silver. For example, 11 grs. of the alloy require 1000 grs. of the normal solution, and 50 grs. of the decimal solution of salt, for the working of the assay. The amount found necessary is, therefore, 35 grs. of the decimal solution, which is equal to 3·5 of the normal solution, which added on to the 1000 grs. makes the total quantity required for the precipitation of the silver 1003·5. Therefore—

	Salt-solution		Salt-solution		Silver		Silver
	1000	:	1003·5	:	10	:	10·035
Then as							
	Alloy		Alloy		Silver		Silver
	11 grs.	:	1000	:	10·035	:	912·2

The weight of alloy operated on should contain about 10 grs. of silver. The contents of silver should, therefore, be approximately determined by cupellation or otherwise before submitting it to assay by this method. It is also desirable to take a quantity of the metal for the assay, so as to require the decimal solution of salt to complete it; by this means the error noticed by Mulder and other assayers is obviated. However, if it is found in the working of an assay that the first 10 grs. of the decimal solution of salt does not yield any precipitate, excess of the decimal solution of silver (1000 grs.

of which contain 1 gr. of silver) is added, and the assay completed as before with the decimal salt-solution. The measure of decimal solution of salt corresponding to the measure of the decimal solution of silver added, is deducted, and the remainder equals the quantity of salt solution required to precipitate the silver in the metal operated on.

b. By weighing the chloride of silver.—This process is used for the Indian Mint assays, special apparatus being employed to carry on a number of assays at one time. The process may be conducted as follows:—A portion of the silver, or alloy, is accurately weighed, transferred to a stoppered bottle, dilute nitric acid added, and solution effected by heating the bottle in a water-bath or otherwise. When decomposed, the solution is diluted with water, hydrochloric acid added in excess, and the bottle well shaken till the precipitated chloride of silver collects, and the solution is clear. The bottle is now filled to the neck with water, allowed to settle, and the supernatant liquor carefully removed by means of a glass syphon. The bottle is again filled with water, the chloride of silver allowed to settle, and the solution syphoned off as before. Two or more washings are made, according to the purity of the silver or alloy operated on. The bottle is now inverted over a small Wedgwood crucible, and manipulated until the whole of the chloride of silver is collected therein. The chloride of silver is now broken up and gently stirred, by means of a glass rod, until it lies evenly at the bottom of the crucible. The water is carefully drained off, and the crucible heated at first at a low temperature, and afterwards for some time at a temperature of about 300° F. When the chloride of silver is thoroughly dried, it is allowed to cool, and then carefully transferred to the skiff of the assay balance, and weighed. The amount of chloride of silver obtained from a known weight of pure silver by working under similar conditions is ascertained, and the calculations made from this data. Special weights are used in India, to facilitate calculations. The assay weight indicating from the amount of chloride of silver the actual quantity of silver present in 1,000 parts.

SILVER COINAGE IN 1873.

	Weight	Number of pieces	Value	
	ozs.		£	s.
Florins . .	2,169,360,000	5,965,740	596,574	0
Shillings . .	1,179,360,000	6,486,480	324,324	0
Sixpences . .	399,600,000	4,395,600	109,890	0
Fourpences .	252,000	4,158	69	6
Threepences .	184,524,000	4,059,528	50,744	2
Twopences . .	144,000	4,752	39	12
Pence . .	120,000	7,920	33	0

SILVER, BROMIDE OF (AgBr), is occasionally found native. If a soluble bromide is added to a solution of nitrate of silver, a precipitate of bromide of silver is formed of a very pale yellow colour. This salt changes readily under the action of the solar rays, and for photographic purposes possesses many very important properties, of which photographers have not availed themselves. This is mainly owing to the neglect of scientific investigation amongst the body of photographic artists, which is exceedingly to be regretted.

SILVER, CHLORIDE OF, (AgCl) is obtained by adding hydrochloric acid, or any soluble chloride, to a solution of nitrate of silver. A curdy precipitate falls, quite insoluble in water, which being dried and heated to dull redness, fuses into a semi-transparent grey mass, called, from its appearance, *horn-silver.* Chloride of silver dissolves readily in water of ammonia, and crystallises in proportion as the ammonia evaporates. It is not decomposed by a red heat, even when mixed with calcined charcoal; but when hydrogen or steam is passed over the fused chloride, hydrochloric acid exhales, and silver remains. When fused along with potash (or its carbonate), the silver is also revived; while oxygen (or also carbonic acid) gas is liberated, and chloride of potassium is formed. Alkaline solutions do not decompose chloride of silver. When this compound is exposed to light, it suffers a partial decomposition, hydrochloric acid being disengaged.

The best way of reducing the chloride of silver, says Mohr, is to mix it with one-third of its weight of colophony (black resin), and to heat the mixture moderately in a crucible till the flame ceases to have a greenish-blue colour; then suddenly to increase the fire, so as to melt the metal into an ingot.

The subchloride may be directly formed by pouring a solution of proto-chloride of copper or iron upon silver-leaf.

SILVER, CYANIDE OF. See Cyanides.

SILVER FIR. *Abies picea.* This species yields the Burgundy pitch and Strasburg turpentine. See Abies.

SILVER, FULMINATING. See Fulminating Silver.

SILVER GLANCE. Sulphide of silver. See Silver.

SILVER, HYPOSULPHITE OF. $AgO.S^2O^2.HO$ ($\mathbf{Ag^2S^2H^2O^4}$). This salt is formed in the process of fixing photographic pictures with *hyposulphite of soda.* Solutions of the hyposulphite of soda, potash, or lime, which are bitter salts, dissolve chloride of silver into liquids possessing a remarkable sweetness. See Hyposulphite of Soda.

SILVER, IODIDE OF. (AgI.) This compound of iodine and silver, which is obtained when a solution of an iodide is added to nitrate of silver, is a pale yellow powder. It is also found native, but not in large quantities. This silver salt is remarkable, like some other metallic compounds, for changing its colour alternatively with heat and cold. If a sheet of white paper be washed over with a solution of nitrate of silver, and afterwards with a somewhat dilute solution of iodide of potassium, it will immediately assume the pale yellow tint of the cold silver iodide. On placing the paper before the fire, it will change colour from a pale primrose to a gaudy brilliant yellow, like the sunflower; and on being cooled, it will again resume the primrose hue. These alternations may be repeated indefinitely, like those with the salts of cobalt, provided too great a heat be not applied. The pressure of a finger upon the hot yellow paper makes a white spot, by cooling it quickly. Iodide of silver, when quite pure, is very slowly darkened when exposed to sunshine; but if in combination with an organic compound, or with an excess of nitrate of silver, it changes colour with much rapidity. From this property it furnishes one of the most valuable of our photographic agents. It is the active material in the calotype, the collodion, the Daguerreotype, and other processes, See Photography.

SILVER, NITRATE OF. $AgO.NO^5$ ($\mathbf{AgNO^3}$). This salt was known to Geber, and was chiefly used in medicine; but since the discovery of photography, it has been made on a very large scale. It is found in commerce in two different forms, viz. crystallised, and in sticks, the former being more general; in sticks it is called 'lunar caustic,' and is used by the surgeon. It is prepared by digesting metallic silver with moderately strong nitric acid; the silver speedily dissolves, especially if heat be applied. Some of the nitric acid is decomposed, yielding oxygen to the silver, and liberating binoxide of nitrogen, which, in contact with the air, abstracts oxygen and forms red vapours of hyponitric acid.

The clear solution is evaporated, either to the crystallising point or to dryness; if for *caustic*, it is fused and cast into sticks. If ordinary standard silver be used, the solution will contain some nitrate of copper; in this case it must be evaporated to dryness, and gradually heated till all the nitrate of copper is decomposed, which may be known by taking a little of the salt, dissolving in water, and adding excess of ammonia; when, if copper be still present, the solution will have a blue tint. When all the copper is thus rendered insoluble, the fused mass is dissolved in distilled water, evaporated and crystallised. When pure, nitrate of silver is white; the crystals are transparent, colourless, hexagonal tables, or right rhombic prisms, very soluble in water, requiring only their own weight of cold water and half that quantity of boiling water for solution; they are also readily soluble in hot alcohol, but the greater portion is again deposited on cooling. Nitrate of silver possesses a strongly metallic and bitter taste. It is not deliquescent, and when free from organic matter is not decomposed by light (*Scanlan*). The dark colour of the outside of the ordinary sticks of the shops is caused by the decomposition of the nitrate by the paper in which they are wrapped, as the presence of organic matter reduces the silver to the metallic state. Nitrate of silver is frequently adulterated to a considerable extent, principally with nitrate of potash, but sometimes with other nitrates. The price at which it is sometimes sold is proof enough that it is largely adulterated; for instance, it may sometimes be bought for 3*s.* an ounce; at that price it does not pay for the silver alone that *should be* in it: we will prove this. Every ounce (437·5 grains) of pure nitrate of silver contains 278 grains of pure silver, and this itself, without taking notice of nitric acid and time of preparation, is worth 3*s.* 2*d.* This clearly proves there must be considerable adulteration; but although the adulterating substances do not interfere generally with the photographic processes, it is certain that no advantage can be gained by buying it at so low a price. The way to detect the adulteration is to precipitate the silver by hydrochloric acid, and evaporate the filtered liquid to dryness, when, if the salt is pure, there will be no residue.

As many, who use much nitrate of silver in photography, &c., throw away the residues, and hence in course of time waste much silver, it will not be out of place here to show how it may be saved and converted again into nitrate of silver fit for use.

If the papers, on which there is silver, are preserved, the silver can be obtained by merely burning them, and may be fused in a porcelain crucible into one lump. In the case of the nitrate-of-silver baths, when too weak for further use, the silver may be precipitated in the form of chloride, by adding hydrochloric acid. The chloride of silver thus obtained may be easily reduced to the metallic state: 1st, by digesting the moist chloride with metallic zinc and dilute sulphuric acid; the hydrogen which is thus liberated reduces the silver to the metallic state, which remains in the form of a black powder, and when well washed with water may be dissolved in nitric acid, evaporated and crystallised. 2nd, by digesting it by the aid of heat with a caustic alkali and tartaric acid, when it will also be reduced to metallic silver, and will remain as a black powder, which may be treated as above. 3rd, by collecting the precipitated chloride of silver on a filter, washing well with water, and drying; the dry chloride is then mixed with four or five times its weight of a mixture of carbonate of potash and carbonate of soda, and subjected to a white heat in a porcelain crucible; the silver will be reduced to the metallic state. This salt is used not only in photography, but in making permanent ink, and as a dye for the hair.

SILVER, OXIDES OF. There are two oxides of silver: the *protoxide* AgO ($\mathbf{Ag^2O}$) and the *peroxide* AgO^2 ($\mathbf{AgO}$). The first is obtained by adding solution of caustic potash, or lime-water, to a solution of nitrate of silver. The precipitate has a brownish-grey colour, which darkens when dried, and contains no combined water. Its specific gravity is 7·143. On exposure to the sun it gives out a certain quantity of oxygen, and becomes a black powder. This oxide is an energetic base; being slightly soluble in pure water, reacting like the alkalis upon reddened litmus-paper, and displacing, from their combinations with the alkalis, a portion of the acids with which it forms insoluble compounds. It is insoluble in the caustic lyes of potash or soda. By combination with caustic ammonia, it forms *fulminating silver*. The second, or peroxide, is formed when a very dilute solution of nitrate of silver is decomposed by the voltaic current; dark grey lustrous needles of the peroxide of silver are formed around the positive pole. See Fulminating Silver.

SILVER, SULPHATE OF, $AgO.SO^3$ ($\mathbf{Ag^2SO^4}$) may be prepared by boiling sulphuric acid upon the metal. It dissolves in 88 parts of boiling water, but the greater part of the salt crystallises in small needles as the solution cools. It consists of 118 parts of oxide, combined with 40 parts of dry acid.

SILVER, SULPHIDES OF, of which several exist native, may be readily prepared by fusing the constituents together. A sulphide forms spontaneously upon the surface of silver exposed to the air of inhabited places. The tarnish may be easily removed by rubbing the metal with a solution of *chameleon mineral*, prepared by calcining peroxide of manganese with nitre. Sulphide of silver is a powerful sulpho-base; since though it be heated to redness in close vessels, it retains the volatile sulphides, whose combinations with the alkalis are decomposed at that temperature. It consists of 87·04 of silver and 12·96 of sulphur.

SILVER-LEAF is made by beating silver out very thin, in precisely the same way as *gold-leaf* is manufactured. See Gold Beating.

SILVERING is the art of covering the surfaces of bodies with a thin film of silver. This is now effected either by applying thin films of silver mechanically to the article to be silvered, or by the electro-metallurgical process. When silver-leaf is to be applied, the methods prescribed for gold-leaf are suitable. Among the metals, copper or brass are those on which the silverer most commonly operates. Iron is seldom silvered; but the processes for both metals are essentially the same. The white alloy of nickel is now often plated.

The principal steps of this operation are the following:—

1. The *smoothing down* the sharp edges, and polishing the surface of the copper; called *emorfiler* by the French artists.

2. The *annealing;* or, making the piece to be silvered red hot, and then plunging it in a very dilute nitric acid, till it be bright and clean.

3. *Pumicing;* or, clearing up the surface with pumice-stone and water.

4. The *warming*, to such a degree merely as, when it touches water, it may make a slight hissing sound; in which state it is dipped in the very weak aquafortis, whereby it acquires minute insensible asperities, sufficient to retain the silver-leaves that are to be applied.

5. The *hatching*. When these small asperities are inadequate for giving due solidity to the silvering, the plane surfaces must be hatched all over with a graving tool; but the chased surfaces need not be touched.

6. The *blueing*, consists in heating the piece till its copper or brass colour changes to blue. In heating, they are placed in hot tools made of iron, called *mandrins* in France.

7. The *charging*, the workman's term for silvering. This operation consists in

placing the silver-leaves on the heated piece, and fixing them to its surface by burnishers of steel, of various forms. The workman begins by applying the leaves double. Should any part darken in the heating, it must be cleared up by the scratch-brush.

The silverer always works two pieces at once; so that he may heat the one, while burnishing the other. After applying two silver-leaves, he must heat up the piece to the same degree, as at first, and he then fixes on with the burnisher four additional leaves of silver; and he goes on *charging* in the same way, 4 or 6 leaves at a time, till he has applied, one over another, 30, 40, 50, or 60 leaves, according to the desired solidity of the silvering. He then burnishes down with great pressure and address, till he has given the surface a uniform silvery aspect.

Silvering by the precipitated chloride of silver.—The white curd obtained by adding a solution of common salt to one of nitrate of silver is to be well washed and dried. One part of this powder is to be mixed with 3 parts of good pearlash, 1 of washed whiting, and one and a half of sea-salt. After cleaning the surface of the brass, it is to be rubbed with a bit of soft leather, or cork moistened with water, and dipped in the above powder. After the silvering, it should be thoroughly washed with water, dried, and immediately varnished. Some use a mixture of 1 part of the silver precipitate, with 10 of cream of tartar, and this mixture also answers very well.

Others give a coating of silver by applying with friction, in the moistened state, a mixture of 1 part of silver-powder precipitated by copper, 2 parts of cream of tartar, and as much common salt. The piece must be immediately washed in tepid water very faintly alkalised, then in slightly warm pure water, and finally wiped dry before the fire.

The inferior kinds of plated buttons get their silver coating in the following way:—

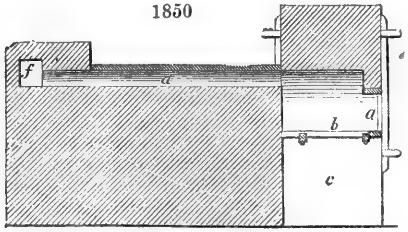
Two ounces of chloride of silver are mixed up with 1 ounce of corrosive sublimate, 3 pounds of common salt, and 3 pounds of sulphate of zinc, with water, into a paste. The buttons being cleaned, are smeared over with that mixture, and exposed to a moderate degree of heat, which is eventually raised nearly to redness, so as to expel the mercury from the amalgam formed by the reaction of the horn-silver and the corrosive sublimate. The copper button thus acquires a silvery surface, which is brightened by cleaning and burnishing. See Electro-Metallurgy.

SILVERING OF GLASS. See Mirrors.

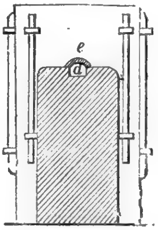
SIMILOR. A name given to a rich-coloured brass, composed of 3 oz. of zinc to 1 lb. of copper. See Alloy and Brass.

SINGEING. In the article Bleaching, the modern and most approved singeing apparatus is described. The old furnace for singeing cotton goods is represented in longitudinal section, *fig.* 1850, and in a transverse one in *fig*, 1851. *a* is the fire-door; *b*, the grate; *c*, the ashpit; *d*, a flue, 6 inches broad and $2\frac{1}{2}$ high, over which a hollow semi-cylindrical mass of cast iron *e*, is laid, 1 inch thick at the sides, and $2\frac{1}{2}$ thick at the top curvature. The flame passes along the fire-flue *d*, into a side opening *f*, in the chimney. The goods are swept swiftly over this ignited piece of iron, with considerable friction, by means of a wooden roller, and a swing frame for raising them at any moment out of contact.

1850



1851



In some shops, semi-cylinders of copper, three-quarters of an inch thick, have been substituted for those of iron, in singeing goods prior to bleaching them. The former last three months, and do 1,500 pieces with one ton of coal; while the latter, which are an inch and a half thick, wear out in a week, and do no more than from 500 to 600 pieces with the same weight of fuel.

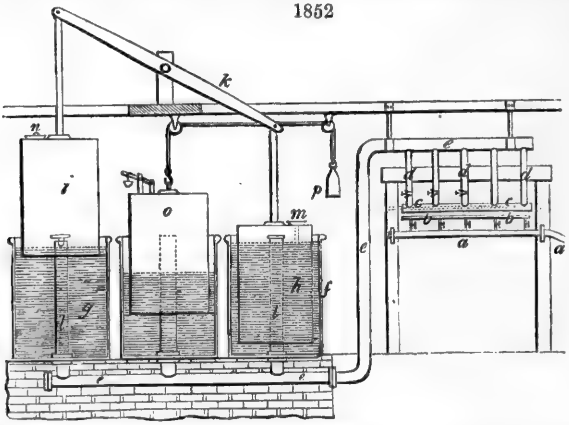
In the early part of the year 1818, Mr. Samuel Hall introduced the plan for removing the downy fibres of the cotton thread from the interstices of bobbinet lace, or muslins, by singeing the lace with the flame of a gas-burner. And in 1823 he modified this process by causing a strong current of air to draw the flame of the gas through the interstices of the lace, as it passes over the burner, by means of an aperture in a tube placed immediately above the row of gas-jets, which tube communicates with an air-pump or exhauster.

Fig, 1852 shows the construction of the apparatus complete, and manner in which it operates: *a*, *a*, is a gas-pipe, supplied by an ordinary gasometer; from this pipe, several small ones extend upwards to the long burner *b*, *b*. This burner is a horizontal tube, perforated with many small holes in the upper side, through which, as jets, the gas passes; and when it is ignited, the bobbinet lace, or other material intended to be singed, is extended and drawn rapidly over the flame, by means of rollers, which are not shown in the figure.

The simple burning of the gas, even with a draught chimney, is found not to be at all times efficacious. There is now introduced a hollow tube *c*, *c*, with a slit or opening, immediately over the row of burners; and this tube, by means of the pipes *d*, *d*, *d*, communicates with the pipe *e*, *e*, *e*, which leads to the exhausting apparatus.

This exhausting apparatus consists of two tanks, *f* and *g*, nearly filled with water, and two inverted boxes or vessels, *h* and *i*, which are suspended by rods to the vibrating beam *k*: each of the boxes is furnished with a valve opening upwards; *l*, *l*, are pipes extending from the horizontal part of the pipe *e*, up into the boxes or vessels *h* and *i*, which pipes have valves at their tops, also opening upward. When the vessel *h* descends, the water in the tank forces out the air contained within the vessel at the valve *m*; but when that vessel rises again, the valve *m* being closed, the air is drawn from the pipe *e*, through the pipe *l*. The same takes place in the vessel *i*, from which the air in its descent is expelled through the valve *n*, and in its ascent draws the air through the pipe *l*, from the pipe *e*. By these means, a partial exhaustion is effected in the pipe *e*, *e*, and the tube *c*, *c*; to supply which, the air rushes with considerable force through the long opening of the tube *c*, *c*, and carries with it the flame of the gas-burners. The bobbinet lace, or other goods, being now drawn over the flame between the burner *b*, *b*, and the exhausted tube *c*, *c*, by means of rollers, as above said, the flame of the gas is forced through the interstices of the fabric, and all the fine filaments and loose fibres of the thread are burnt off, without damaging the substance of the goods.

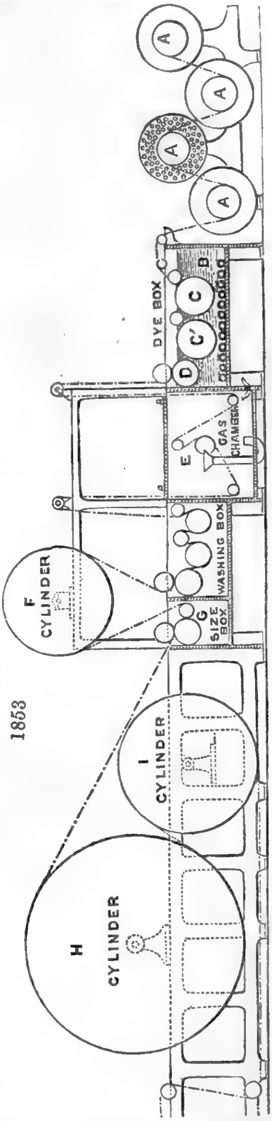
1852



To adjust the draught from the gas-burners, there are stop-cocks introduced into several of the pipes *d*; and to regulate the action of the exhausting apparatus, an air vessel *o* is suspended by a cord or chain passing over pulleys, and balanced by a weight *p*. There is also a scraper introduced into the tube *c*, which is made, by any convenient contrivance, to revolve and slide backwards and forwards, for the purpose of removing any light matter that may arise from the goods singed, and which would otherwise obstruct the air-passage. Two of these draught tubes *c* may be adapted and united to the exhausting apparatus, when a double row of burners is employed, and the inclination of the flame may be directed upwards, downwards, or sideways, according to the position of the slit in the draught tube, by which means any description of goods may, if required, be singed on both sides at one operation.

SIZE. A solution of gelatinous matter, usually made from skin, employed for the purpose of giving adhesiveness to certain substances, which could not be otherwise secured to surfaces. See GELATINE and GLUE

SIZING AND DYEING MACHINE. The process of sizing and dyeing of yarns has usually been effected by two processes. The yarn was dyed in the bale warp, and in that state each thread was not equally exposed to the dye; and then the system of ball-warp sizing was adopted. Dawson and Slater have recently introduced a new process, by which the yarn is both dyed and sized at the same time. This is effected by passing the yarn first through a solution of the colouring-matter, and the mordant held in solution by some acid, then through ammoniacal vapour, and lastly through the size-box. The process is as follows:—Beginning with the four-warp roller A A (at the right hand of the machine) as seen in *fig.* 1853), the yarn passes thence into the dye-vessel B, over three guide-rollers to a copper cylinder C, thence over another guide-roller to a second copper cylinder, eventually coming up through the two squeezing rollers D, at the end of the dye-box. It may be observed, that the copper cylinders can be raised or lowered in the dye-box by means of a rack and pinion, and that the small circles at the bottom of the dye-vessel represent steam-pipes for boiling the dye-liquor. The yarn then passes from the squeezing rollers over other rollers into the ammoniacal or gas-chamber E, which, with the exception of two openings, the one for the passing in of the yarn, and the other for letting it out, is wholly closed by the lid here represented in the centre of the chamber. By following the dotted lines, it will be perceived that herein the yarn passes under and over four guide-rollers before its exit from the chamber, it being during the passage fully exposed to the vapour of the ammonia, which is introduced by means of the funnel represented in the centre. Thence the yarn passes into the next vessel termed the washing-box or chamber, over and under suitable rollers and through the two squeezing rollers at the end, there being a perforated pipe, not shown in the drawing, for discharging water on to the yarn. Coming out of the washing-box, the yarn continues its journey over a steam-drying cylinder F, down into the size-box G below, the smaller circle in the engraving representing a guide-roller, and the others two copper squeezing rollers. Then the yarn, after leaving the squeezing rollers, passes over and under a larger cylinder H, and a smaller drying cylinder I, whence it is conveyed by suitable rollers to the weaver's beam as marked.


1853

The advantages of this arrangement are that the yarn is less strained, less crossed, and in a better condition for weaving. It enters the size and the dye in the form of a sheet, in which state each thread is separated, and completely surrounded by the dye, and afterwards by the size; the result is uniformity of shade and an absence of streaky or uneven places. Not only so, but there is a great saving of time, for warps in the grey in the morning may be dyed, sized, and in the loom weaving by noon of the same day, and all done on the manufacturer's own premises and under his supervision, contrasting very favourably with the old plan of getting the work done out of doors. By that system the time that elapses from sending the warps to the dyer to receiving them back again is frequently ten days to a fortnight, which necessitates the keeping of a larger stock than is requisite by the new plan, when all is done in a few hours.

To illustrate the principle of these improvements, one example will suffice. Suppose that a black dye is required; a coloured solution is made by boiling about 100 parts of logwood of good quality in 600 parts of water; after which twelve parts of sulphate of iron and two parts of sulphuric acid are added. A sufficient quantity of this solution is introduced into the dye-trough, so as to cover the rollers therein. The solution is kept on the boil by means of the coil of steam-piping placed at the bottom, and the yarn is drawn through the solution, and, passing thence through the chamber containing the ammoniacal vapour on to the drying cylinders, it ends its course on the loom-beam, unless otherwise required. See CALICO-PRINTING.

SKATES. The fishes comprehended under the genus *Raia.* There are many species, the most common being the blue or grey skate, *Raia batis.* Some of this species weigh as much as 200 lbs. The thornback, or rough ray, is the *Raia clavata*; and the homelyn, or sand ray, *Raia miraletus.* All three are good eating; the last is the most common in our markets.

SKIN. (*Peau*, Fr.; *Haut*, Ger.) The external membrane of animal bodies consists of three layers: 1. the epidermis, or scarf-skin (*Oberhaut*, Ger.); 2, the vascular organ, or papillary body, which performs the secretions; and 3, the true skin (*Lederhaut*, Ger), of which leather is made. The skin proper, or dermoid substance, is a tissue of innumerable very delicate fibres, crossing each other in every possible direction, with small orifices between them, which are larger on its internal than on its external surface. The conical channels thus produced are not straight, but oblique, and filled with cellular membrane; they receive vessels and nerves which pass out through the skin (*cutis vera*), and are distributed upon the secretory organ. The fibrous texture of the skin is composed of the same animal-matter as the serous membranes, the cartilages, and the cellular tissue; the whole possessing the property of dissolving in boiling water, and being, thereby, converted into glue. The skins of animals are imported for the preparation of furs, for use, and ornament, and for the manufacture of leather. See GLUE, LEATHER, TAN, and FURS.

In 1873 our *Imports* of skins, furs, and pelts were as follow:—

	Number	Value
		£
Goat and kid, undressed	1,358,895	174,093
„ „ tanned, tawed, or dressed	5,456,709	623,087
Seal	876,077	427,274
Sheep and lamb, undressed	8,363,736	1,322,848
„ „ tanned, tawed, or dressed	3,760,619	313,369
Unenumerated, being furs	4,026,665	419,104
„ not being furs, dressed and undressed	3,768,970	458,998
Skins and furs manufactured	...	30,677
Specimens illustrative of natural history	...	36,021

SLAG. (*Laitier*, Fr.; *Schlacke*, Ger.) This is the vitreous mass which covers the fused metal in the smelting-hearths. In the iron-works it is commonly called *cinder.* Slags consist, in general, of bi-silicates of lime and magnesia, along with the oxides of iron and other metals; being analogous in composition, and having the same crystalline form in some cases as the mineral *pyroxene*; in others as that of *olivine.*

The following, selected from the analyses of Percy and Forbes, show the composition of the iron-furnace slags:—

Silica	28·32	42·06	39·52	29·60
Alumina	24·24	12·93	15·11	41·28
Lime	40·12	32·53	32·52	0·47
Magnesia	2·79	1·06	3·49	0·35
Protoxide of manganese	0·07	2·26	2·89	1·13
Protoxide of iron	0·27	4·94	2·02	48·43
Sesquioxide of iron	...	...	...	17·11
Potash, with traces of soda	0·64	2·69	1·06	...
Sulphate of lime	0·26	...	...	...
Sulphide of calcium	3·38	1·03	2·15	...
Phosphoric acid	...	0·31	...	1·34
Sulphide of iron	...	...	...	1·61
Loss	...	0·19	1·24	...
	100·09	100·00	100·00	101·32

Of the last of these, Dr. Percy remarks:—

'An immense quantity of iron slag, *far richer than many iron ores*, is annually thrown away, and it may be that the presence of phosphoric acid in sensible quantity is one of the causes which prevents the re-smelting of this slag to advantage. The fact has not yet sufficiently attracted the attention of those engaged in the manufacture of iron. The discovery of a method of extracting economically good iron from these rich slags would be of great advantage to the country, and could not fail amply to reward its author.'

Numerous attempts have been made to utilize the slags produced in great quantity from our blast furnaces, but hitherto no process appears to have been attended with success. One of the most recent attempts has been that of Mr. Charles Wood, of Middlesbro'. He employs a machine for caking the slag, which is simply a horizontal rotative table on which the slag flowing from the slag-spout of the blast-furnace is deposited and slowly borne round in a continuous layer of from half an inch to three-quarters of an inch in thickness. The table is composed of thick slabs of iron with water flowing freely through them to keep them cool. The thin layer of slag is solidified by the cool slabs, then water is allowed to flow freely on it, and scrapers placed athwart the table break the friable material into pieces and gather it right away into the waggons. Mr. Wood attempts to prove by comparative statements that great economy would be effected by the use of the caked slag and slag-sand as concrete, and of the slag-sand mixed with lime as a mortar. The slag-sand is prepared by allowing the molten slag to flow from the furnace into a rotating drum containing water; the slag falling into the water is disintegrated to a coarse powder.

Blast-furnace slags have been much used for road-mending, but they do not answer well on account of their extreme brittleness. This fault can, however, be to a great extent remedied by devitrifying them. This is done by allowing them to cool very slowly. The slag, by a process introduced by Mr. Egleston, is cast in huge blocks, which are then subjected to pressure; after the blocks are cold they are found to possess much toughness, and are said to furnish an excellent material for road-making.

For many years past the slags of copper furnaces have been used for building purposes, and to a less extent the slags from blast-furnaces. Processes are now being practised, which though somewhat complicated and troublesome, furnish blocks which are completely impervious to damp, possess the necessary toughness, and are admirably suited for the foundation of buildings.

In one plan, when the furnace is tapped, the slag is allowed to run into a semicircular vessel, which being on wheels, is readily brought to and from the furnace. At the bottom of this vessel, is a layer of sand and coke dust three centimeters thick. A bent rake or paddle is then employed to mix thoroughly the slag with the sand and cinders, until the gases cease to be evolved, and the mass is nearly solid. The semi-solid mass is then ladled into moulds, provided with iron lids, which are fixed down as soon as no more bubbles of gas appear. When completely solid, but while still red hot, the block is placed in an annealing oven, and covered with coke-dust, so that the complete cooling shall not take place in less than three or four days.

When the slag contains 38 per cent. and upwards of silica, a serviceable building stone can be obtained from it by simply taking care that the annealing process is sufficiently long. This is in some works effected by allowing the whole of the slag to run down a shoot into a pit lined with sand and ashes, with which it is also covered up. If proper precautions have been taken to prevent premature chilling, it will be nearly ten days before the slag is sufficiently pasty to allow of its being filled into moulds. The blocks are, subsequently, as carefully cooled as in the former process.

In some parts of Belgium the slag is met, as it leaves the blast-furnace, by a stream of water, with the effect of breaking it up into a powder even finer than sand. This product the puddlers use for making the moulds for their pig-iron, and greatly prefer it to sand. A kind of glass is also made by running the slag on iron plates, which are afterwards cooled by the judicious application of water. The slag-powder is also used for mortar-making. Very rapid hardening is said to be thus secured, a point of great importance in the building of foundation-walls and all subsoil erections. Bricks are, in some parts of Europe, glazed by powdering them with slag before drying, and afterwards burning them out of contact with carbon. The glaze thus produced is very perfect, and as the slags are of different colours a variety of tints are obtained. Tiles, drain-pipes, and earthenware generally may be thus treated. It has been tried how far a mixture of clay and granulated slag may with advantage be used for fire-bricks. The results of its use in a brass furnace are said to have been exceedingly satisfactory.

SLATES. (*Ardoises*, Fr.; *Schiefer*, Ger.) The substances belonging to this class may be distributed into the following species:—1. Mica-schist, occasionally used for covering houses. 2. Roofing slate. 3. Whet slate. 4. Polishing slate. 5. Drawing slate, or black chalk. 6. Adhesive slate. 7. Bituminous shale. 8. Slate-clay.

1. *Mica-schist,* sometimes called *Mica-slate.*—This is a rock occupying a vast extent, in some mountain chains: it is of a schistose texture composed of the minerals mica and quartz, the mica being generally predominant.

2. *Roofing-slate.*—This substance is closely connected with mica-slate; so that uninterrupted transitions may be found between these rocks in many mountain chains. It is a simple schistose mass, of a bluish-grey or greyish-black colour, of various shades, and a shining, somewhat pearly internal lustre on the faces, but of a dead colour in the cross fracture.

This slate is extensively distributed in Great Britain. It skirts the Highlands of Scotland, from Loch Lomond by Callender, Comrie, and Dunkeld; resting on, and gradually passing into mica-slate throughout the whole of that territory. Roofing-slate occurs on the western side of England, in the counties of Cornwall and Devon; in various parts of North Wales and Anglesea; in the north-east parts of Yorkshire, near Ingleton, and in Swaledale; as also in the counties of Cumberland and Westmoreland. It is likewise met with in the counties of Wicklow and other mountainous districts of Ireland.

All the best beds of roofing-slate improve in quality as they lie deeper under the surface; near to which, indeed, they have little value. This variety of slate is found in the Cambrian, Silurian, and Devonian formations.

A good roofing-slate should split readily into thin even laminæ: it should not be absorbent of water either on its face or endwise, a property evinced by its not increasing perceptibly in weight after immersing in water; and it should be sound, compact, and not apt to disintegrate in the air. The slate raised at Eisdale, on the west coast of Argyleshire, is very durable. The slates of Penrhyn and other quarries in North Wales are very celebrated; those of Delabole in Cornwall are also well known and much esteemed.

Cleaving and Dressing of the Slates.—The splitter begins by dividing the blocks, cut lengthwise, to a proper size, which he rests on end, and steadies between his knees. He uses a mallet and a chisel, which he introduces into the stone in a direction parallel to the cleavage planes. By this means he reduces it into manageable pieces, he gives to each the requisite length, by cutting cross grooves on the flat face, and then striking the slab with the chisel. It is afterwards split into thinner sections, by finer chisels dexterously applied to the edges. The slab is then dressed to the proper shape, by being laid on a block of wood, and having its projecting parts at the ends and sides cut off with a species of hatchet or chopping-knife. It deserves to be noticed that blocks of slate may lose their property of divisibility into thin laminæ. This happens from long exposure to the air, after they have been quarried. The workmen say, then, that they have lost their waters. For this reason, the number of splitters ought to be always proportionate to the number of block-hewers. Frost renders the blocks more fissile; but a supervening thaw renders them quite refractory. A new frost restores the faculty of splitting, though not to the same degree; and the workmen therefore avail themselves of it without delay. A succession of frosts and thaws renders the quarried blocks quite intractable.

3. *Whet slate, or Turkey hone,* is a slaty rock, containing a great proportion of quartz, in which the component particles, the same as in clay-slate and mica-slate, but in different proportions, are so very small as to be indiscernible.

4. *Polishing slate.* Colour, cream-yellow, in alternate stripes; massive; composition impalpable; principal fracture, slaty, thin, and straight; cross fracture, fine earthy; feels fine, but meagre; adheres little, if at all, to the tongue; is very soft, passing into friable; specific gravity, in the dry state, 1·6; when imbued with moisture, 1·9. It is supposed to have been formed from the ashes of burnt coal. It is found at Planitz near Zwickau, and at Kutschlin near Bilin in Bohemia.

5. *Drawing slate, or Black chalk,* has a greyish-black colour; is very soft, sectile, easily broken, and adheres slightly to the tongue; spec. grav. 2·11. The streak is glistening. It occurs in beds in primitive and transition clay-slate; also in secondary formations, as in the coal-measures of most countries. It is used in crayon-drawing. Its trace upon paper is regular and black. The best kinds are found in Spain, Italy, and France. Some good black chalk occurs also in Caernarvonshire and in the island of Islay.

6. *Adhesive slate* has a light greenish-grey colour, is easily broken or exfoliated, has a shining streak, adheres strongly to the tongue, and absorbs water rapidly, with the emission of air-bubbles and a crackling sound.

7. *Bituminous shale* is a species of soft, sectile slate-clay, much impregnated with bitumen, which occurs in the coal-measures. See KIMMERIDGE SHALE, and SHALES.

8. *Slate-clay* has a grey or greyish-yellow colour; is massive, with a dull glimmering lustre from spangles of mica interspersed. Its slaty fracture approaches at times to earthy; fragments, tabular; soft, sectile, and very frangible; specific gravity,

2·6. It adheres to the tongue, and crumbles down when immersed for some time in water. It is the *Killas* of the Cornish miners.

In addition to the slates properly so called, many fissile rocks, which split along planes of bedding into sufficiently thin slabs to be used for roofing, are popularly called 'slates.' Thus the *Stonesfield slate* is a thin-bedded arenaceous limestone, at the base of the Great Oolite, largely quarried at Stonesfield, in Oxfordshire. The *Colleyweston slate* is a similar fissile limestone, belonging to the Lincolnshire (Inferior) Oolite, which is worked at Colleyweston, in Northamptonshire, and is much used by Sir Gilbert Scott for roofing churches built in the Gothic style. The *Duston slate* is a similar material occurring in the Northampton sands.

SLATY CLEAVAGE. See CLEAVAGE.

SLIDES. *A miner's term* for a dislocation of the strata, which is evidenced by the sliding of one portion of the rock over the other. These slides are often, but not always, filled with a softer matter than the rock, a clay in a greater or less state of induration.

SLIKENSIDES. The name given to smooth striated surfaces of rocks or of mineral lodes, indicating the grinding action of the movement of heavy masses. Many polished surfaces are called *slikensides* to which the term is evidently inapplicable.

SLIP. A fracture of strata, with the levels of the relative beds altered on the opposite sides of the fracture: the beds are thus slipped out of their original position.

SLOKE. The common name for *laver*. See ALGÆ.

SMALT. A beautiful blue glass made by melting cobalt ore with flint and potash. It is largely prepared in Saxony; for an account of its manufacture, see COBALT. The chemical composition of a specimen of German smalt was as follows:—Silica, 66·20; potash and soda, 16·31; oxide of cobalt, 6·49; alumina, 0·43; oxide of iron, 0·24; arsenic, a trace; water, &c., 0·57.

SMALTINE. See COBALT.

SMECTITE. A name given to a kind of fuller's earth, found in Lower Styria.

SMITHSONITE. See CALAMINE; ZINC.

SMELTING. The processes for obtaining the metals from the ores. These are described under their respective heads. See COPPER, IRON, LEAD, SILVER, TIN, ZINC, &c.

SMOKE. The more volatile portions of coal, passing off, charged with finely-divided carbon, at a comparatively low temperature.

If the black smoke, which escapes from a furnace when a quantity of cold coals is thrown in upon an incandescent mass, can be made to pass over another portion of coal in active combustion, this carbon is consumed, *i.e.* combined with atmospheric oxygen, and converted into carbonic oxide, which burns, producing carbonic acid; and it therefore eventually escapes as colourless vapour.

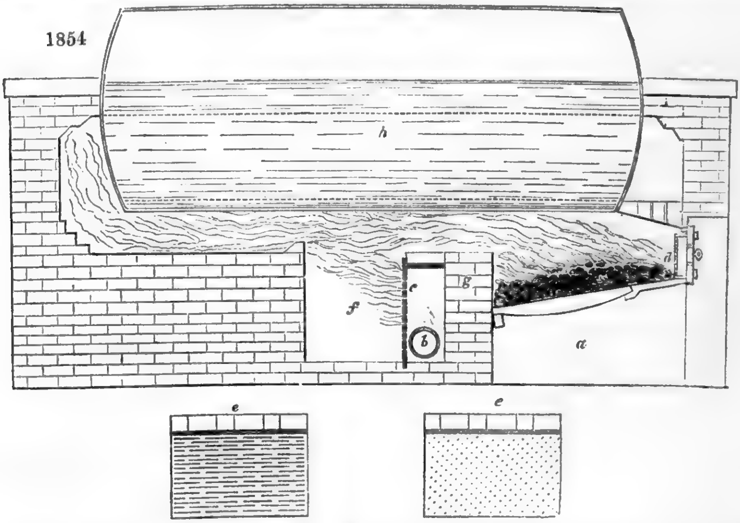
One great cause, and perhaps the greatest cause of the annoyance of smoke in large towns is the carelessness of the man supplying fuel to the fire. Where coal is abundant, the stoker usually piles an unnecessary quantity of fuel upon his fire, and this has the effect of reducing the heat, and of producing dense volumes of black smoke. Where coal is scarce and dear, as in Cornwall, careful stoking leads to an almost entire absence of smoke. A small quantity of coal is placed in front of the fire at a time; here it undergoes a coking process, the volatile carbon passing over the heated coal is burnt, and no visible smoke escapes. When the coal is thoroughly coked, it is shovelled in over the fire, and a fresh portion of coal is placed in front, to undergo the same process.

Prevention of Smoke.—The attention of the legislature has been directed to this nuisance, and sundry Acts have been passed to regulate and reduce the evil. The following extract from the 'Act to Amend the Smoke Nuisance Abatement (Metropolis) Act' (16 & 17 Vict. cap. cxviii.) August 20, 1853, should have every attention from manufacturers:—

'From and after the 1st day of August 1854, every furnace employed or to be employed in the metropolis in the working of engines by steam, and every furnace employed or to be employed in any mill, factory, printing-house, dye-house, iron-foundry, glass-house, distillery, brew-house, sugar-refinery, bake-house, gas-works, water-works, or other buildings used for the purpose of trade or manufacture within the metropolis (although a steam-engine be not used or employed therein), shall in all cases be constructed or altered so as to consume or burn the smoke arising from such furnace; and if any person shall, after the 1st day of August 1854, within the metropolis, use any such furnace which shall not be constructed so as to consume or burn its own smoke, *or shall so negligently use any such furnace*, as that the smoke arising therefrom shall not be effectually consumed or burnt, or shall carry on any trade or business which shall occasion any noxious or offensive effluvia, or otherwise annoy the neighbourhood or inhabitants, without using the best practical means for preventing or counteracting such smoke or other annoyance, every person so offending, being the *owner or occupier of the premises, or being a foreman or other* *person employed by such owner or occupier*, shall, upon a summary conviction for such offence before any justice or justices, forfeit and pay a sum not more than 5*l.* nor less than 40*s.*, and upon a second conviction for such offence, the sum of 10*l.*, and for each subsequent conviction, a sum double the amount of the penalty imposed for the last preceding conviction: provided always, that nothing in this Act shall extend or apply to any glass-works or pottery-works established and existing within the metropolis before the passing of this Act, with the exception, however, of all steam-engine furnaces and slip-kiln furnaces employed in and belonging to such works respectively, to which furnaces the provisions of this Act shall extend and apply.'

'An Act to Amend the Smoke Nuisance Abatement (Metropolis) Act, 1853.' (July 29, 1856.) 'From and after the 1st day of January 1858, the above-mentioned provision whereby certain furnaces in glass-works and pottery-works were exempted from the operation of the said Act shall be repealed; and all steam-vessels plying to and fro between London Bridge and any place on the river Thames to the westward of the Nore Light shall be subject to the provisions of the said recited Act relating to steam-vessels above London Bridge.

1854



'And whereas it is expedient that furnaces employed in public baths and wash-houses should be included within the provisions of the said recited Act: be it enacted, that from and after the said 1st day of January 1858, every furnace employed or to be employed in any such public baths and wash-houses in the metropolis, although the same shall not be used for the purposes of trade or manufacture, shall be, and the same is hereby included in and made liable to all the provisions of the said recited Act.'

Among the numerous inventions which have been patented for effecting this purpose, with regard to steam-boilers and other large furnaces, very few are sufficiently economical or effective. The first person who investigated this subject in a truly philosophical manner was Mr. Charles Wye Williams, managing director of the Dublin and Liverpool Steam Navigation Company, and he also has had the merit of constructing many furnaces, both for marine and land steam-engines, which thoroughly prevent the production of smoke, with increased energy of combustion, and a more or less considerable saving of fuel, according to the care of the stoker. The specific invention, for which he obtained a patent in 1840, consists in the introduction of a proper quantity of atmospheric air to the bridges and flame-beds of the furnaces, through a greater number of small orifices, connected with a common pipe or canal, whose area can be increased or diminished according as the circumstances of complete combustion may require, by means of an external valve. The operation of the air thus passed in small jets into the half-burned carburetted hydrogen gases over the fires, is their perfect combustion, the development of all the heat which they can produce, and the entire prevention of smoke. One of the many ingenious methods in which Mr. Williams has carried out the principles of what he justly calls his Argand furnace, is represented by *fig.* 1854, where *a* is the ash-pit of a steam-boiler furnace; *b* is the mouth of a tube which admits the external air into the chamber or iron box of distribution, *c*, placed immediately beyond the fire-bridge, *g*, and before the diffusion or mixing chamber, *f*. The front of the box is perforated either with round or oblong orifices, as shown in the two small figures *e*, *e*, beneath *fig.* 1854; *d*, is the fire-door, which may have its fire-brick lining also perforated. In some cases, the fire-door projects in front, and it, as well as the sides and arched top of the fire-place, are constructed of perforated fire-tiles, enclosed in common brickwork, with an intermediate space, into which the air may be admitted in regulated quantity through a moveable valve in the door. Fire-places of this latter construction perform admirably without smoke, with an economy of one-seventh of the coals usually consumed in producing a like amount of steam from an ordinary furnace; *h* is the steam-boiler.

Evidence was presented some years ago to the Smoke Prevention Committee of the House of Commons of the successful application of Mr. Williams's patent invention to many furnaces of the largest dimensions, more especially by Mr. Henry Houldsworth, of Manchester, who, mounting in the first flue a pyrometrical rod, which acted on an external dial-index, succeeded in observing every variation of temperature produced by varying the introduction of the air-jets into the mass of ignited gases passing out of the furnace. He thereby appeared to demonstrate, that 20 per cent. more heat could be obtained from the fuel, when Mr. Williams's plan was in operation than when the fire was left to burn in the usual way, and with the production of the usual volumes of smoke.

It should be borne in mind that *consumption* of smoke implies cleanliness, economy of health, and economy of labour. Are not these sufficient reasons to induce manufacturers to use the best means possible to do away with a great nuisance, and to avoid the waste of so precious a commodity as coal, for a time may come when we shall have cause to regret our extravagant consumption of that article? We have shown that the cause of smoke is incomplete combustion, caused either by the want of a sufficient quantity of air, or by such air being admitted under such circumstances that its admission is worse than useless. Experience has proved that there are but few difficulties in constructing arrangements which will effect the consumption of smoke; but desirable as the process is, it must be admitted that smoke-consuming is not found to be economical, although it is in every sense desirable.

By means of Wright's patent smoke-consumer, the air admitted into the furnace is regulated by a self-acting ventilating door, so as to furnish the necessary amount of oxygen requisite for perfect combustion. The air is also diffused over the entire surface of the fire. By this apparatus, a partially-decomposed and nearly red-hot jet of steam is projected from over the door down upon the incandescent fuel. By that means the fire becomes brighter, not damped, as it would be were wet steam used, and not only causes a vacuum in the furnace, thereby increasing the draught, but effectually prevents the cold air admitted through the door and the gases distilled from the coal from touching the boiler-plates, thus avoiding—

1. The cooling of the boiler-plates by the action of the cold air striking them, and causing the continual expansion and contraction of the metal, which is so injurious to boilers.

2. The gases formed by the first action of the hot furnace on the coal thrown in from coming in contact with the top of the furnace or boiler-plates, the temperature of which being no greater than that of the contents of the boiler, can only cool those gases to such an extent that their combination with oxygen cannot take place.

Not only are these two great evils avoided, but the jet of steam forces the gases distilled from the coal on to the incandescent fuel at the back of the furnace, together with the air admitted through the door, thus multiplying the points of contact *ad infinitum*, thereby causing instantaneous combination of their elements, making the combustion as perfect as it can be in a manufacturing point of view; and obtaining all the heat that the combination of oxygen with the hydrogen and carbon can give. The smoke is never allowed to pass the bridge of the furnace; in fact, its forming is prevented. The apparatus is simple and efficient in its action, not liable to get out of repair. It can be applied in two days at the utmost, and has been frequently fitted in one day, and it is adapted for every description of furnace. Under all circumstances, however, it has been proved that careful stoking is the best method for preventing the escape of smoke.

SMOKY QUARTZ. A variety of quartz having a smoke-coloured tint: it comprises the clove-brown variety of *cairngorms*.

SOAP is a chemical compound, manufactured on a very extensive scale, forming, accordingly, a considerable article of commerce. It is a compound resulting from the combination of certain constituents derived from fats, oils, grease of various kinds, both animal and vegetable, with certain salifiable bases, which, in detergent soaps, are potash or soda.

Oils and fats consist chiefly of oleine and stearine, as in tallow, suet, and several vegetable fats; of margarine, which occurs in animal fats, in butter, in olive and other vegetable oils; of palmitine, which is found in palm oil; and so on with various other immediate principles, according to the nature of the fats and oils employed by the soap-maker. Natural fatty substances, however, are never exclusively formed of one of these principles, but are, on the contrary, composed of several of them in various proportions, oleine alone being a constant constituent in all of them.

Natural or neutral fats and oils, chemically considered, are really salts, sometimes called 'glycerides;' that is to say, are combinations of acids, oleic, stearic, margaric, acid, &c., with the oxide of a hypothetical radical called *glyceryl*.

Stearine being, therefore, a combination of stearic acid with oxide of glyceryl, is a stearate of oxide of glyceryl.

Oleine is a combination of oleic acid with oxide of glyceryl, and is, therefore, an oleate of oxide of glyceryl.

Margarine is a combination of margaric acid and oxide of glyceryl, and is, therefore, a margarate of oxide of glyceryl, and so on with the other constituents of fats and oils.

Glycerine is a combination of oxide of glyceryl with water, which, in that case, plays the part of an acid to form a hydrate of oxide of glyceryl (glycerine).

Now, when neutral fats (namely, oleine, stearine, margarine, &c., or the fats or oils which they constitute) are treated by solutions of caustic alkalis, such as potash or soda, their constituents react upon each other, and combine with the potash or soda; and provided too great an excess of alkali has not been used, the fat or oil dissolves in the alkaline solution into a syrupy liquid, which on cooling forms a gelatinous mass which is nothing else than an aqueous solution of soap mixed with the glycerine, which the treatment has set free.

The following equation, in which, for the sake of simplicity, one of these principles only, *stearine*, and soda dissolved in water, are taken as examples, will clearly illustrate this interesting reaction:—

$$\overbrace{\text{Stearate of oxide of glyceryl}}^{\text{Stearine.}} + \text{soda} + \text{water}$$
$$= \underbrace{\text{stearate of soda}}_{\text{hard soap.}} + \underbrace{\text{hydrate of oxide of glyceryl}}_{\text{glycerine.}}$$

In the same way:—

$$\overbrace{\text{Oleate of oxide of glyceryl}}^{\text{Oleine.}} + \text{soda} + \text{water}$$
$$= \underbrace{\text{oleate of soda}}_{\text{hard soap.}} + \underbrace{\text{hydrate of oxide of glyceryl}}_{\text{glycerine.}}$$

According to the modern views of chemists, however, glycerine may be regarded as propenylic alcohol, one of the group of triatomic alcohols. The natural fats then become triatomic ethers of the fatty acids; thus stearine (tristearine) consists of propenyl tristearate. All soaps are metallic salts of the fatty acids, or mixtures of those salts.

Soaps made with soda are hard; those made with potash are soft; the degree of hardness being so much greater as the melting-point of the fats employed in their manufacture is higher, hence the more oleine a fatty matter contains, the softer the soap made with it will be, and *vice versâ*. The softest soap, therefore, would be that made altogether with oleine (oleic acid) and potash (oleate of potash); the hardest would be that made with stearine and soda (stearate of soda).

The fats or oils employed for the manufacture of soaps, are tallow, suet, palm oil, cocoa-nut oil, kitchen fat, bone-grease, horse oil or fat, lard, butter, train oil, seal oil, and other fish oils, rape oil, poppy oil, linseed and hempseed oil, olive oil, oil of almonds, sesame, and ground-nut oil, and *resin*. This last substance, though very soluble in alkaline menstrua, is not, however, susceptible, like fats, of being transformed into an acid, and will not, of course, saponify or form a proper soap by itself. The more caustic the alkali the less consistency has the resinous compound which is made with it. The employment of caustic alkalis, however, is not necessary with it, since it dissolves readily in aqueous solutions of carbonated alkalis, but even with carbonate of soda it forms only a viscid mass, owing to its great affinity for water, so that even after having been artificially dried in an oven, and thus rendered to a great extent hard, the mass deliquesces again spontaneously by exposure, and returns to the soft state. The drying oils, such as those of linseed and poppy, produce the softest soaps.

We said that by boiling fats or oils with an aqueous solution of potash or of soda a solution of soap was produced. The object of the soap-maker is to obtain the soap thus produced in a solid form, which is done by boiling the soapy mass so as to evaporate the excess of water to such a point that the soap may separate from the concentrated liquor and float on the surface thereof in a melted state, or by an admixture of common salt, soap being insoluble in lyes of a certain strength or degree of concentration, and in solutions of common salt of a certain strength, the glycerine remaining, of course, in solution in the liquor below the separated soap. Such is the theory of soap-making; but the *modus operandi* followed by practical soap-makers will be described presently.

On the Continent olive oil, mixed with about one-fifth of rape oil, is principally used in making hard soap. This addition of rape oil is always resorted to, because olive oil alone yields a soap so hard and so compact that it dissolves only with difficulty and slowly in water, which is not the case with rape oil and other oils of a similar nature, that is to say, with oils which become thick and viscid by exposure, and which on that account are called drying oils, experience having taught that the oils which dry the soonest by exposure, yield with soda a softer soap than that made with oils which, like olive oil, remain limpid for a long period under the influence of the air. The admixture of rape oil has, therefore, the effect of modifying the degree of hardness of the soap, and, consequently, of promoting its solubility. In England tallow is used instead of olive oil; the soap resulting from its treatment with soda is known under the name of *curd soap*, and is remarkable for the extreme difficulty with which it dissolves in water. The small, white, cubic, waxy, stubborn masses, which until a few years ago were generally met with on the washing-stand of bedrooms in hotels, and which for an indefinite period passed on from traveller to traveller, each in turn unsuccessfully attempting, by various devices and cunning immersions in water, to coax it into a lather, is *curd soap*. Rape or linseed oil, added in certain proportions to tallow, would modify this extreme hardness and difficult solubility, but it is now the general practice to qualify the tallow with cocoa-nut oil, an oil, which, converted into soap, has the property of absorbing incredible quantities of water, so that the soap into the manufacture of which it has entered lathers immediately. Cocoa-nut oil, however, acquires by saponification a most disagreeable odour (due to the formation of caprylic acid), which it imparts to all the soaps in the manufacture of which it enters, an odour which persists in spite of any perfume which may be added to mask it.

The admixture of one-fourth or one-fifth of resin with tallow, in the process of saponification, modifies also the hardness and considerably increases the solubility of curd soap, and this, in fact, constitutes the best *yellow soap*.

It has been said above that soap was more or less hard in proportion as the melting-point of the fats employed in its manufacture was higher or lower. There are certain fatty substances, technically called 'weak goods,' such as kitchen fat, bone-fat, horse oil, &c., which could hardly be used alone, still less with resin, the soap which they yield being too soft, and melting or dissolving away too rapidly in the washing-tub. This led the writer to think, that if a means could be devised of artificially hardening soap, a larger class of oleaginous and fatty substances could be rendered available, at any rate to a greater extent than they theretofore had been, and that, by thus extending the resources of the soap-boiler, he should be enabled to produce a good and useful soap from the cheapest materials, and thus convert soaps of little commercial value into useful and economical products.

In making experiments with this view, he found that the introduction of a small quantity of melted crystals of sulphate of soda into the soap answered the purpose admirably, and that the salt in recrystallising, imparted to the soap, which otherwise would have been soft, a desirable hardness, and prevented its being wasted in the tub. The use of sulphate of soda acts, therefore, *inversely*, like the addition of rape oil, or linseed oil, or of resin to tallow, in the manufacture of soap. This process, which was patented in 1841, has been, since the removal of the duties on soap, extensively employed by soap-makers, and continues to be highly approved of by the public. We shall describe further on the manner of practising this process, and the further improvements which were made to it in 1855.

Of the manufacture of hard soap.—The fat of this soap, in the northern countries of Europe, is usually tallow, and in the southern, coarse olive oil, Different species of grease are saponified by soda, with different degrees of facility; among oils, the olive, sweet almond, rapeseed, and castor oil; and among solid fats, tallow, bone-grease, and butter, are most easily saponified. According to the practice of the United Kingdom, six or seven days are required to complete the formation of a pan of hard soap, and a day or two more for settling the impurities, if it contains resin. From 12 to 13 cwts. of tallow are estimated to produce one ton of good soap. Several years ago, in many manufactories the tallow used to be saponified with potash-lyes, and the resulting soft soap was converted, in the course of the process, into hard soap, by the introduction of muriate of soda, or weak kelp-lyes, in sufficient quantity to furnish the proper quantity of soda by the reaction of the potash upon the neutral salts. But the high price of potash, and the diminished price, as well as improved quality of the crude sodas, have led to their general adoption in soap-works.

The first step in the production of soap consists in obtaining a solution of soda, or what is termed caustic lye. For this purpose a given quantity of the soda-ash above alluded to, is stratified with a quantity of recently-burnt quick-lime, in tanks of wrought-iron, or cylindrical cast-iron vats, from 6 to 7 feet wide and from 4 to 5 feet deep, the lowest layer being, of course, quick-lime. These vats have frequently a false bottom, perforated with holes, or else a coarse piece of matting is placed over the plug-hole, placed at the bottom of the said vats or tanks, which plug-hole is, of course, closed generally by a wooden plug. Water is then poured upon the whole mass until the tanks are full, and the whole is allowed to stand for twelve or eighteen hours. The plug being then withdrawn, the saturated solution of caustic soda flows down into a reservoir placed beneath, after which the plug is replaced, more water applied, and this operation is repeated five or six times, until, in fact, the soda is almost entirely extracted; the various liquors thus obtained, in a clear and caustic state, after infiltration through the beds of lime, being conveyed to separate and distinct reservoirs, distinguished from each other by the names of *first running, second running*, and so on; the last, being, of course, the weakest.

Having in this way produced a series of caustic lyes of different degrees of strength, about 200 gallons of the weakest, which has a specific gravity of about 1·040, is pumped into the soap-pan or boiler, or *copper*, as it is called, though generally made of cast iron, and about 1 ton of tallow is added; heat is applied, and after a gentle ebullition of about four hours, it will be found that the lye will have lost its causticity, or, in technical language, that it is *killed*, and that the fat is saponified, which is known by taking a portion of the mass on a trowel, when it will be observed that the liquid separates at once from the soapy mass, which it leaves in streaks on the towel. The lyes thus used at first, if composed of pure soda, would contain about 4 per cent. of alkali, but from the presence of neutro-saline matter they seldom contain as much as 2 per cent.; in fact, a gallon may be estimated to contain not more than 2 ounces, so that 200 gallons contain 25 lbs. of real soda. The fire being withdrawn, the whole is now allowed to cool and remain at rest for about one hour, until the lye, now deprived of its alkali, and therefore, called *spent lye*, settles to the bottom of the copper. This spent lye contains a portion of glycerine derived from the fat or tallow, together with the sulphate of soda and common salt of the soda-ash, and is pumped off by means of an iron pump, which is lowered down into the lower pan of the soap-copper, a practice which might be advantageously replaced by opening a cock which might be placed at the bottom of the copper, but which is retained as a remnant of that abominable system of excise, which did not permit the spent lyes to be otherwise withdrawn, as the excise laws forbade any cock or aperture being placed or made at the bottom of soap-coppers. This constitutes what is called an operation. A second similar charge of lye is now introduced into the pan along with a fresh quantity of tallow or of grease, and a similar boiling process is again repeated. Three or four such boilings may be practised in the course of a day by an active soap-boiler, with lyes of gradually-increasing strength. Next day the same routine is renewed with stronger lyes, and so progressively until towards the sixth day the lye may have the density of 1·160, when a period arrives at which it will be found that the whole of the tallow or fat is completely saponified, that is to say, has combined with its full equivalent of soda. This point is well known to the workmen by the consistency of the compound; in effect it is sufficient to take a portion of the mass on a trowel, and to squeeze a little of the mass between the forefinger and thumb; if not quite and thoroughly finished it will still have a greasy feel, but if done it will on cooling readily separate from the skin in hard scales; neither has it the taste peculiar to grease. A more certain mode, however, especially for those who have not acquired sufficient practice, is to decompose a portion of the saponified or partly-saponified mass with an acid, and to ascertain whether the grease is *wholly soluble* in boiling spirits of wine, for if it is not thus wholly soluble, the saponification is imperfect. The addition of common salt for the separation of the spent lyes is essential to the proper granulation and separation of the soap, for otherwise the tallow and the lye would unite into a uniform emulsion, from which it would be very difficult afterwards to separate the spent lye; but as soap is quite insoluble in a solution of common salt, the partly-saponified mass is thus brought to float on the surface, so that the spent lye precipitates to the botttom, whence as we said, it is pumped off.

Assuming, however, that a perfect result has been secured, the soap has now to be brought to a marketable condition, and for this purpose it is boiled with a quantity of weak lye or water. As soon as combination has taken place, a quantity of very strong lye is added, until an incipient separation begins to show itself. The heat is now increased, and the boiling continued for a considerable time, the mass being prevented from boiling over the vessel by workmen armed with shovels, who dash the soap to and fro, so as to break the froth upon the surface and favour evaporation. At first the soap is divided into an innumerable number of small globules, each separate and distinct from its fellow; but as the boiling goes on, those gradually run together into larger and larger globules, till at last the soap is seen to assume a pasty consistency, and to unite in one uniform mass, through which the steam from below slowly forces its way in a series of bursts of little explosions. The process is now finished, and all that remains to be done is to shut down the lid of the copper, having previously extinguished the fire. In from one to two or three days, according to the nature and quantity of the soap in question, the lid is again raised, and the semifluid soap ladled from the precipitated lye by means of ladles; the product being thrown into a wooden or iron frame of specific dimensions, where its weight is estimated by measurement. In making common yellow or resin soap, the resin is usually added after the saponification of the tallow, in the proportion of one-third or one-fourth of the tallow employed. The subsequent operations are much about the same as those above described; but in addition, just before closing the lid of the copper a quantity of water or weak lye is sprinkled over the melted soap, which carries down with it the mechanical impurities of the resin; and these constitute a dark layer of soap resting upon the lye, which is not poured into the frame with the rest, but is placed apart under the name of '*niger*,' and brings a less price. Good curd or white soap should contain of grease, 61·0 parts; soda, 6·2; water, 32·8; total 100; or consist of grease-acid, 1 atom = 315; soda, 1 atom = 32; water, 17 atoms = 153. Resin soap has a more variable composition, but when not adulterated with water should contain about as follows: grease and resin, 60; soda, 6; water 34; total 100.

Manufacture of mottled soap.—Soda which contains sulphides is preferred for making the mottled or marbled soap, whereas the desulphuretted soda makes the best white curd soap. Mottling is usually given in the London soap-works, by introducing into the nearly-finished soap in the pan a certain quantity of the strong lye of crude soda, through the rose spout of a watering-can. The dense sulphuretted liquor, in descending through the pasty mass, causes the marbled appearance. In France a small quantity of solution of sulphate of iron is added during the boiling of the soap, or rather with the first service of the lyes. The alkali seizes the acid of the sulphate, and sets the protoxide of iron free to mingle with the paste, to absorb more or less oxygen, and to produce thereby a variety of tints. A portion of oxide combines also with the stearine to form a metallic soap. When the oxide passes into the red state, it gives the tint called *manteau Isabelle.* As soon as the *mottler* has broken the paste, and made it pervious in all directions, he ceases to push his rake, from right to left, but only plunges it perpendicularly till he reaches the lye; then he raises it suddenly in a vertical line making it act like the stroke of a piston in a pump, whereby he lifts some of the lye, and spreads it over the surface of the paste. In its subsequent descent through the numerous fissures and channels on its way to the bottom of the pan, the coloured lye impregnates the soapy particles in various forms and degrees, whence a varied marbling results.

The best and most esteemed soap on the Continent is that known under the name of Marseilles soap, and it differs from the English mottled soap by a different disposition of the mottling, which in that soap is granitic instead of being streaky. It has also an agreeable odour, somewhat resembling that of the violet, whereas the English mottled soap, generally made of coarse kitchen and bone-fat, has an odour which reminds one of the fat employed. The best English mottled soap in which tallow is employed has no unpleasant smell, and if bleached palm oil has been used it acquires an agreeable odour, analogous to that of the Marseilles soap, which is made of olive oil alone, or mixed with rape or other grain or seed oil, which, however, seldom exceeds 10 per cent., for otherwise it would not have the due proportion of blue to the white which is characteristic of soap made of genuine olive oil, the mottling becoming more closely granular when an undue proportion of grain has been used, a sign of depreciation which the dealers are perfectly well acquainted with, and of which they at once avail themselves, to compel the maker to reduce his price.

Pelouze and Frémy, in their *Traité de Chimie générale*, give the following reliable observations:—

'The best olive oil for the use of the soap-maker is Provence oil; that of Aix comes next; it is cheaper, but the same weight of it yields less soap than the other, and the latter has then a slight lemon-yellow tinge. The oil from Calabre contains less margarine, and yields a softer soap.

'Two kinds of soda-ash are used in Marseilles—the soft soda (*soude douce*) and the salted soda (*soude salée*), which contains a large quantity of common salt.

'To prepare the lye, the soft soda previously reduced into small lumps is mixed with 12 per cent. of slaked lime, and shovelled up into tanks of masonry of about 2 cubic yards' capacity, called *barquieux*, and the exhaustion of the mass with water gives lyes of various degrees of strength.

'The lye marking 12° is used for the first treatment, or *empâtage* of the oil which is then submitted to a second and third treatment with a lye marking 15° or 20°, the object of which is to close the grains of the emulsive mass in process of saponification (*serrer l'empâtage*). The operation requires about twenty-four hours. During all the time of that operation a workman is constantly agitating the boiling mixture of the oil and lye by means of a long rake or crutch, called *râble*. The *empâtage* is generally practised in large conical tanks of masonry terminated at bottom by a copper-pan, and capable of containing 12 or 13 tons of made soap, and the operation proceeds so much the more rapidly, as the soda-lye employed contains less common salt, wherefore soft soda-lye (*soude douce*) must be used at the beginning, as we said.

'The next operation is that called *relargage*, the object of which is to separate the large quantity of water which has been used to facilitate the *empâtage*. This separation of the water, or *relargage*, is effected by means of salted soda (that is to say, of soda-ash, containing a good deal of common salt), of which as much is dissolved in water as will make a lye marking 20° or 25°. This salted lye is then gradually poured by a workman on the surface of the saponifying goods in the copper, while another workman is diffusing it in the mass by stirring the whole with a rake or crutch.

'The immediate effect of the salt thus added is to separate from the soapy mass the water in which it was dissolved, and which gave it a homogeneous and syrupy appearance, and to coagulate it, the soap being thereby cured or coagulated, and converted into a multitude of granules floating among the excess of water in which they were dissolved, and which the salt has separated. The whole being then left at rest for two or three hours, in order to give the grains of soap time to rise and agglomerate at the surface, a workman proceeds to the *épinage*, an operation which consists in withdrawing the liquid portion by removing a wooden plug placed at the lower part of the boiler.'

In this country the *épinage* is generally performed by means of an iron pump plunging through the soap down to the pan at the bottom of the copper.

This *spent lye*, in well-conducted factories, retains but little alkali, and is generally thrown away; but as it contains a rather large quantity of salt, which, in France, is an expensive article, it might be, and is sometimes, kept and used for preparing fresh lyes.

After the first *épinage*, the soap is treated twice again with salt-lye, followed of course by two *épinages*; but as the salt-lye used in these two operations is not exhausted, it is always kept for preparing fresh lyes.

The cleansing, that is to say, the removing of the soap into the frames, takes place on the third day, at which time the operation called *madrage* is performed. For that purpose a plank is thrown across the boiler or copper, and two or three men standing on it, and therefore over the soapy mass in the copper, proceed to stir it up for two or three hours, by means of long crutches, which they alternately move up and down through it, the object being to keep the grains of soap well diffused through the liquid, weak lyes marking only 8° or 10°, or ordinary water, as the case may be, being sprinkled from time to time into the mass, until the grains of soap have reabsorbed a sufficient quantity of water and have swollen to such a size as to have a specific gravity very little greater than that of the liquid in which they float about. A skilful workman knows by the appearance of the soap grains whether he should use alkaline lyes or simple water, and this is indeed a most important point in the manufacture of *Marseilles* soap, for upon it the success of the operation depends in a commercial point of view, that is to say, all things being equal in other respects, a profit or loss on the batch of soap made will ensue. In effect, if too much water has been added the soap will lose either the whole, or too great a portion of its *mottling*, that is to say, the result will be either a dingy white curd, or a soap in which the white portions will predominate to too great an extent over the blue streaks; a circumstance which so far deteriorates the market value, the buyer shrewdly suspecting then that he would pay for water the price of soap. If, on the contrary, a sufficient quantity of water has not been added, the soap grains remaining hard and dry, will form a more or less friable soap, thereby causing also a deterioration of price, the buyer knowing that such soap, by crumbling into small pieces every time he has to cut it with his knife in selling it to his customers, will considerably reduce his profit, or perhaps even entail a positive loss to him

In the best conditions, that is to say, by employing the best Gallipoli oil for the purpose of producing Marseilles soap of first quality, 100 cwts. of olive oil yield 175 cwts. of mottled soap; by using mixtures of olive and rape or other seed oils, the yield of soap is reduced to 170, or even less; in either case the yield is reduced by 5 or 6 per cent., when old or fermented is employed instead of new good oil.

The manufacturing expenses are calculated at Marseilles at the rate of 17f. 25c. (nearly 13*s.* 10*d.*) per 100 kilogrammes of fatty matter employed, which require 72 kilogrammes of soda for their saponification.

Mottled soap has a marbled, or streaky appearance, that is to say, it has veins of a bluish colour, and resembling granite in their disposition or arrangement. The size and number of these veins or speckles, and the proportion which they bear to the white ground of the soap, depend not only on the more or less rapid cooling of the soap after it has been cleansed, that is, transferred from the copper to the frame; but also on the quality and kind of the fat, grease, or oil employed, and on the manner in which it has been treated in the copper. A soap which has not been sufficiently boiled at the last stage of the manufacture is always tender. The blue or slate colour of the streaks or veins of mottled soap is due to the presence of an alumino-ferruginous soap interposed in the mass, and frequently also to that of sulphide of iron, which is produced by the reaction of the alkaline sulphides contained in the soda-lye upon the iron, derived from the soda-ash itself, and from the iron pans and other utensils employed in the manufacture, or which is even purposely introduced in the state of solution of protosulphate of iron. This introduction, however, is never resorted to, we believe, in this country. The veins or streaks disappear from the surface to the centre by keeping, because the iron becomes gradually peroxidised. A well-manufactured mottled soap cannot contain more than 33, 34, or at most 36 per cent. of water, whereas genuine curd soap contains 45, and yellow soap at least 52 per cent. of water, and sometimes considerably more than that. It is evident, in effect, that the mottling being due to the presence of sulphide of iron held in the state partly of demi-solution and of suspension, the addition of water would cause the colouring substances to subside, and a white, unicoloured, or 'fitted' soap would be the result. This addition of water, technically called *fitting*, is made when the object of the manufacturer is to obtain a unicoloured soap, whether it be curd or yellow soap. After *fitting*, the soap contains, therefore, an additional quantity of water, which sometimes amounts to 55 per cent.: the interest of the consumer would, therefore, clearly be to buy mottled soap in preference to yellow or white soap; the mottling, when not artificially imitated, being a sure criterion of genuineness; for the addition of water, or of any other substance, would, as was just said, infallibly destroy the mottling. To yellow or curd soap, on the contrary, incredible quantities of water may be added. The writer has known five pails of water (15 gallons) added to a frame (10 cwts.) of already *fitted* soap, so that the soap, by this treatment, contained upwards of 60 per cent. of water, to which common salt had previously been added. The proportion of water in fitted soap has also been augmented, in some instances, by boiling the soap in high-pressure boilers before *cleansing*. As cocoa-nut oil has the property of absorbing one-third more water, when made into soap, than any other material, its consumption by the soap-maker has, within the last twenty-five years, augmented to an extraordinary extent; and, moreover, the patent taken in 1857 by Messrs. Blake and Maxwell, of Liverpool, for the invention of Mr. Kottula, which will be described presently, has, we believe, increased the demand for that species of oil in a notable degree. We said that the mottling, inasmuch as it was indicative of genuineness, was the more economical soap to buy; unfortunately, mottled soap has the drawback of not being so readily soluble as yellow soap, and the goods washed with it are more difficult to rinse; but the process patented by Messrs. Blake and Maxwell enabling the manufacturer to manufacture with cocoa-nut oil a soap to which the mottling is artificially impaired, by means of ultramarine, black or brown oxide of manganese, in such a perfect manner as almost to defy detection, mottling has thus ceased to be a safe outward sign of genuineness, as far as regards the article which it pretends to represent. That description of soap, however, has specific qualities: it is almost perfectly neutral, and it will not bear more than a definite proportion of water; so that, although it contains more of that liquid than ordinary mottled soap, more than a certain fixed quantity cannot be forced into it; hence it also forms a standard soap, like the ordinary mottled, although that standard is different from, and inferior to, the latter. The process in question is briefly as follows:—Take 80 cwts. of palm oil, made into soap in the usual way, with two changes of lye, grained with strong lye, or lye in the usual manner, but that the lye leaves the curd perfectly free; pump the spent lye away, and add 32 cwts. of cocoa-nut oil, 60 cwts. of lye, at 20° of Beaumé's aëreometer, and then gradually 14 cwts. of lye, at 14° Beaumé. Boil until the whole mass is well saponified. Put now from 6 to 7 lbs. of ultramarine in water, or weak lye, stir the whole well, and pour it into the soap through the rose of a watering-pot; boil the whole for about half an hour, or an hour, and cleanse it in the ordinary wooden frames or in iron frames surrounded by matting, or other covering, so that the soap may not cool too rapidly; the above proportions will yield 212 cwts. of soap, with a beautiful blue mottle.

Manufacture of Yellow or Resin Soap.—We have already said that resin, though not capable of forming a soap with soda, readily dissolves in that alkali, either in the caustic or in the carbonated state, with which it forms a kind of soapy mass of a viscid or treacly nature; hence fat of some kind, in considerable proportion must be used along with the resin, the *minimum* being equal parts; and then the soap is far from being good. As alkaline matter cannot be neutralised by resin, it preserves its peculiar acrimony in a soap poor in fat, and is ready to act too powerfully upon woollen and all other animal fibres to which it is applied. It is said that rancid tallow serves to mask the strong odour of resin in soap more than any oil or other species of fat. From what we have just said, it is obviously needless to make the resin used for yellow soaps pass through all the stages of the saponifying process; nor would this indeed be proper, as a portion of the resin would be carried away, and wasted with the spent lyes. The best mode of proceeding, therefore, is first of all to make the hard soap in the usual manner, and at the last service or charge of lye, namely, when this ceases to be absorbed, and preserves in the boiling-pan its entire causticity, to add the proportion of resin intended for the soap. In order to facilitate the solution of the resin in the soap, it should be reduced to coarse powder, and well incorporated by stirring with the rake. The proportion of resin is usually from one-third to one-fourth the weight of the tallow. The boil must be kept up for some time with an excess of caustic lye; and when the paste is found, on cooling a sample of it to acquire a solid consistency, and when diffused in a little water, not to leave a resinous varnish on the skin, we may consider the soap to be finished. The maker next proceeds to draw off the superfluous lyes, and to purify the paste. For this purpose, a quantity of lyes at 80° B. being poured in, the mass is heated, worked well with a rake, then allowed to settle, and drained of its lyes. A second service of lyes at 4° B., is now introduced, and finally one at 2°; after each of which there is the usual agitation and period of repose. The pan being now skimmed, and the scum or *fob* removed for another operation, the soap is laded off by hand-pails into its frame-moulds. A little palm oil is occasionally employed in the manufacture of yellow soap, in order to correct the flavour of the resin and brighten the colour. This soap, when well made, ought to be of a fine wax-yellow hue, be transparent upon the edges of the bars, dissolve readily in water, and afford, even with hard pump-water, an excellent lather.

The frame-moulds for hard soap are composed of strong wooden bars, made into the form of a parallelogram, which are piled over each other, and bound together by screwed iron rods that pass through them. A square well is thus formed, which in large soap-factories is sometimes 10 feet deep, and capable of containing a couple of tons of soap. For plain yellow or curd soaps, iron frames are now used instead of wooden ones, in almost every factory.

Mr. Sheridan some time since obtained a patent for combining silicate of soda with hard soap, by triturating them together in the hot and pasty state with a crutch in an iron pan. In this way from 10 to 30 per cent. of the silicate may be introduced. Such soap possesses very powerful detergent qualities, but it is apt to feel hard and be somewhat gritty in use. The silicated soda is prepared by boiling ground flints in a strong caustic lye, till the specific gravity of the compound rises to nearly double the density of water. It then contains about 35 grains of silica, and 46 of soda-hydrate, in 100 grains.[1]

Hard soap, after remaining two days in the frames, is at first divided horizontally into parallel tablets 3 or 4 inches thick, by a brass-wire; and these tablets are again cut vertically into an oblong nearly square bars, called 'wedges' in Scotland.

The soap-pans used in the United Kingdom are made of cast iron, and in three separate pieces joined together by iron-rust cement. The following is their general form:—The two upper frusta of cones are called curbs; the third, or undermost, is the pan to which alone the heat is applied, and which, if it gets cracked in the course of boiling, may easily be lifted up within the conical pieces, by attaching chains or cords for raising it, without disturbing the masonry in which the curbs are firmly set. The surface of the hemispherical pan at the bottom, is in general about one-tenth part of the surface of the conical sides.

The white ordinary tallow soap of the London manufacturers, called curd soap, consists, by the writer's experiments, of fat, 52; soda, 6; water, 42 = 100. Nine-tenths of the fat, at least, is tallow.

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[1] By the writer's own experiments upon the liquid silicate made at Mr. Gibbs's excellent soap factory.

With respect to the manufacture of sulphated soap, the process is as follows:—

To every ton of soap made in the usual way and ready to be cleansed and crystallised, add sulphate of soda (Glauber's salt) in the proportion of about 1 cwt. or more, according to the quality of the goods employed. The Glauber's salt should first be dissolved by turning steam into it, or in a steam-pan, in its own water of crystallisation; it is then added to the finished soap, and the whole must be crutched until the mass has become so stiff that it cannot be crutched any longer. In the evidence before the Privy Council, in the month of July 1855, this process was found by their Lordships of such public value that the patent right was extended for three years.

This process, however, has been superseded by another which Dr. Normandy patented in the month of August 1855. In effect it had been found that whereas sulphate of soda is more soluble in lukewarm than in either cold or boiling water, the temperature of the weather in summer time interfered with or altogether prevented the formation of the crystals, and that as the crystals of this salt contain ten equivalents of water, the maker of sulphated soap was put to the trouble and expense of the carriage of this, to him useless, water of crystallisation.

Soft Soap.—The manufacture of soft soap differs greatly from that of hard soap; as, in this case, nothing is separated from the mixture in the boiler; and the alkali employed is potash, and not soda. The mode of obtaining a caustic lye of potash is exactly the same as with soda, except that the weak lyes are used in place of water for a subsequent operation, and not pumped up into the boiler. The materials employed as fats are mixtures of the vegetable and animal oils, as rape, and the fish oil called 'Southern.' For the best kinds of soft soap, a little tallow is added to these, which produces a peculiar kind of mottling or crystallisation in the soap, that confers additional value upon it. These oils or fats are merely boiled with the strong caustic potash-lye, until thorough combination has taken place, and so much of the water of the lye is evaporated that, when a portion of the soap is poured upon a cold slab and allowed to rest for a few minutes, it assumes the consistency of soft butter. As soon as this happens, the whole is run out into little casks, where it cools; it is thus sent into the market. Of course no atomic arrangement can be traced in so variable a compound; and hence its analysis presents no point of interest. The employment of soft soap is daily becoming more and more limited.

The principal difference between soaps with base of soda, and soaps with base of potash, depends upon their mode of combination with water. The former absorb a large quantity of it, and become solid; they are chemical hydrates. The others experience a much feebler cohesive attraction; but they retain much more water in a state of mere mixture.

Three parts of fat afford, in general, fully five parts of soda-soap, well dried in the open air; but three parts of fat or oil will afford from six to seven parts of potash-soap of moderate consistency. This feebler cohesive force renders it apt to deliquesce, especially if there be a small excess of the alkali. It is therefore impossible to separate it from the lyes; and the washing or *relargage*, practised on the hard-soap process is inadmissible in the soft. Perhaps, however, this concentration or abstraction of water might be effected by using dense lyes of muriate of potash. Those of chloride or sulphide of sodium change the potash into a soda-soap, by double decomposition. From its superior solubility, more alkaline reaction, and lower price, potash-soap is preferred for many purposes, and especially for scouring woollen yarns and stuffs.

Soft soaps are usually made in this country with whale, seal, olive, and linseed oils, and a certain quantity of tallow; on the Continent, with the oils of hempseed, sesame, rapeseed, linseed, poppy-seed, and colza; or with mixtures of several of these oils. When tallow is added, as in Great Britain, the object is to produce white and somewhat solid grains of stearic soap in the transparent mass, called *figging*, because the soap then resembles the granular texture of the fig.

The potash-lyes should be made perfectly caustic, and of at least two different strengths; the weakest being of sp. gr. 1·05; and the strongest, 1·20, or even 1·25. Being made from the potashes of commerce, which contain seldom more than 60 per cent., and often less, of real alkali, the lyes correspond in specific gravity to double their alkaline strength; that is to say, a solution of pure potash of the same density would be fully twice as strong. The following is the process followed by respectable manufacturers of soft soap (*savon vert*, being naturally or artificially green) upon the Continent.

A portion of the oil being poured into the pan, and heated to nearly the boiling point of water, a certain quantity of the weaker lye is introduced; the fire being kept up so as to bring the mixture to a boiling state. Then some more oil and lye are added alternately, till the whole quantity of oil destined for the pan is introduced. The ebullition is kept up in the gentlest manner possible, and some stronger lye is occasionally added, till the workman judges the saponification to be perfect. The boiling becomes progressively less tumultuous, the frothy mass subsides, the paste grows transparent, and it gradually thickens. The operation is considered to be finished when the paste ceases to affect the tongue with an acrid pungency, when all milkiness and opacity disappear, and when a little of the soap placed to cool upon a glass-plate assumes the proper consistency.

A peculiar phenomenon may be remarked in the cooling, which affords a good criterion of the quality of the soap. When there is formed around the little patch an opaque zone, a fraction of an inch broad, this is supposed to indicate complete saponification, and is called the *strength;* when it is absent, the soap is said to want its *strength.* When this zone soon vanishes after being distinctly seen, the soap is said to have *false strength.* When it occurs in the best form the soap is perfect, and may be secured in that state by removing the fire, and then adding some good soap of a previous round to cool it down, and prevent further change by evaporation.

200 lbs. of oil require for their saponification, 72 lbs. of American potash of moderate quality, in lyes at 15° B.; and the product is 460 lbs. of well-boiled soap.

If hempseed oil has not been employed, the soap will have a yellow colour, instead of the green, so much in request on the Continent. This tint is then given by the addition of a little indigo. This dye-stuff is reduced to fine powder, and boiled for some hours in a considerable quantity of water, till the stick with which the water is stirred presents, on withdrawing it, a gilded pellicle over its whole surface. The indigo paste diffused through the liquid, is now ready to be incorporated with the soap in the pan before it stiffens by cooling.

Estimation of the quantity of water in soap:—Take about 1,000 grains of the soap under examination, cut into small and thin slices, not only from the outside, which is always drier, but from the interior of the sample, so that the whole may represent a fair average; mix the mass well together, and of this weigh accurately 100 grains; place it in an oven heated to a temperature of 212° Fahr., until it is quite dry, weighing it occasionally until no loss or diminution of weight is observed, the difference between the original and the last weight, the loss, indicates, of course, the proportion of water. The loss of water in mottled soap and in soft soap should not be more than 30 to 35 per cent.; in white or yellow soap from 36 to at most 50 per cent.

If the soap is sulphated, the amount of sulphate employed may be determined by taking 200 grains of the sample, dissolving it in a capsule with boiling water, adding to the boiling solution as much hydrochloric acid as is necessary to render the liquid strongly acid, and therefore to decompose the soap entirely throwing the whole in a filter previously wetted with water, adding to the filtrate an excess of chloride of barium, washing thoroughly the white precipitate so produced, igniting and weighing it; every grain of sulphate of baryta thus obtained represents 1·467 grain of crystallised sulphate of soda.

If the soap contains clay, chalk, silica, dextrine, fæcula, pumice-stone, ochre, plaster, salt, gelatine, &c., dissolve 100 grains of the suspected soap in alcohol, with the help of a gentle heat; the alcohol will dissolve the soap and leave all these impurities in an insoluble state. Good mottled soap should not leave more than 1 per cent. of insoluble matter, and white or yellow soap still less. All soap to which earthy or siliceous matter has been added is opaque instead of transparent at the edges, as is the case with all genuine or fitted and sulphated soap. The drier the soap, the more transparent it is.

Bone-soap, or glue-soap, is recognised by its unpleasant odour of glue and its dark colour, its want of transparency at the edges; that made with the fat of the intestines of animals has a disgusting odour of fæces.

When uncombined silica has been added to soap, its presence may be readily detected by dissolving the suspected soap in alcohol, as before, when the silica will be left in an insoluble state; but if the silica is in the state of silicate of soda or of potash, it is necessary to proceed as follows:—Dissolve a given weight of the suspected soap in boiling water, and decompose it by the gradual addition of moderately dilute hydrochloric acid, until the liquor is strongly acid; boil the whole for one or two minutes longer and allow it to cool in order that the fatty acids having separated and become hard, may be removed. Evaporate the acid liquor to *perfect dryness,* and the perfectly dry mass treated with boiling water will leave an insoluble residue which may be identified as silica by its grittiness, which is recognised by rubbing it in the capsule with a glass rod. This white residue should then be collected on a filter, washed, dried, ignited, and weighed.

The proportion of alkali (potash or soda) may be easily determined by an alkalimetrical assay as follows:—

Take 100 grains of the soap under examination, and dissolve them in about 2,000 grains of boiling water; should any insoluble matter be left, decant carefully the superincumbent solution and test it with dilute sulphuric acid of the proper strength, exactly as described in the article ALKALIMETRY.

The proportion of alkali contained in soap may also be ascertained by incinerating a given weight of soap in an iron or platinum spoon, crucible, or capsule, treating the residue with water, filtering and submitting the filtrate to an alkalimetrical assay. This method, however, cannot be resorted to when the soap contains sulphates of alkalis, because the ignition would convert such salts, or a portion thereof, into carbonates of alkali, which by saturating a portion of the test-sulphuric acid would give an inaccurate result.

The proportion of oil or fat in soap is ascertained by adding 100 grains of pure white wax free from water to the soap-solution, after supersaturation with an acid, and heating the whole until the wax has become perfectly liquid, and has become perfectly incorporated with the oil or fat which has separated by the treatment with an acid. The whole is then allowed to cool, and the waxy cake obtained is removed, heated in a weighed crucible or capsule to a temperature of about 220° Fahr. in order to expel all the water, after which the whole is weighed; the increase above 100 grains (the original weight of the wax) indicates, of course, the quantity of grease, fat, or oil contained in the soap. This addition of wax is necessary only when the fatty matter of the soap is too liquid to solidify well in cooling. Good soap ordinarily contains from 6 to 8 per cent. of soda; from 60 to 70 per cent. of fatty acids and resin, and from 30 to 35 per cent. of water.

The nature of the fat of which a given sample of soap has been made is more difficult to detect, yet by saturating the aqueous solution of the mass under examination with an acid, collecting the fatty acids which then float on the surface, and observing their point of fusion, the operator at any rate will thus be enabled to ascertain whether the soap under examination is identical with the sample from which it may have been purchased, and whether it was made from tallow, or from oil, &c.

	cwts.	value
Our Soap *Exports* were in 1873	183,750	£243,047
,, ,, 1874	219,284	277,207

SOAP-BARK. A few years since a peculiar bark was introduced into the European trade, and recommended to be employed instead of soap for washing and cleaning printed goods, woollens, and silks, and especially for the delicate colours of ladies' dresses, &c. This soap-bark is externally black, but internally the liber consists of layers of yellowish-white. The bark is remarkable for its density, as it sinks in water. The cause of this is the great quantity of mineral substances in its ashes, there being 13·935 per cent. of the internal parts, dried at low temperature and 18·50 per cent. when dried at 100° C. The ashes consist largely of carbonate of lime, which forms 2·60 per cent. of the 13·935, and appears as small crystalline needles, isolated or in groups, in the cells of the liber, not only between its concentric rings but in every part of it. They glitter in the sun, resembling under the microscope, the aragonite form of the crystallised carbonate of lime.

The soap-wort (*Saponaria officinale*) is sometimes used for scouring and cleaning dresses. Several of this family of caryophyllaceous plants (*Dianthus, Lychnis, Gypsophila, Silene*) are remarkable for this property in a greater or less degree. By chemical means there has been extracted from these roots the *Saponine* (or *Struthiine*), a special substance, and to this, notwithstanding the very small quantity contained in the roots, the singular power is attributed of making emulsions, and of being used for soap in washing. The soap-wort of the Levant (*Gypsophila*) is, to this day, employed in the East for washing and cleaning silks and shawls. It is generally used in the Mediterranean districts of France and Spain; the French called it *herbe aux foulons* (the fuller's plant). The *Saponaire*, or *Savonière* of the French, is the root of a kind of *Lychnis*. Saponine was found by Henry and Boutron Charland in the bark of the *Quillaja saponaria*, a tree of the family of rosaceous plants, and a native of Huanaco, in Peru. Ferdinand Lebœuf made mention of this bark in 1850 for its richness in saponine, and recommended it for pharmaceutical use in preparing emulsions of oils, resins, balsams, and several other medicaments. He mentions likewise the bark of the *Yallhoy* (*Monnina polystachya*) as containing saponine. The fruits of *Sapindus saponaria*, known as 'soap-berries,' are used in America and the West Indies for washing linen.

SOAPSTONE. See STEATITE.

SODA. NaO (**Na^2O**). This is the oxide of the metal sodium, and can only be obtained in the free state by the combustion of the metal itself in dry air or oxygen gas. Another oxide appears to exist, but the composition is uncertain, and it is of no commercial value. Soda (*oxide of sodium*), thus prepared, is a white solid, which absorbs moisture rapidly, the whole of which cannot be again removed by heat alone, the hydrate $NaO.HO$ (**$NaHO$**) remaining. This hydrate of soda, which is largely used in the manufacture of soap, is not prepared from the anhydrous oxide, but by removing the carbonic acid from carbonate of soda by the means of hydrate of lime. When the soda is required in the solid state, the carbonate of lime thus formed is allowed to settle, the clear supernatant liquid is poured off and evaporated to dryness, fused in a silver vessel, and cast into sticks.

The following is a table of the quantities of real soda (NaO) in the solutions of different specific gravities.—*By Richter.*

Spec. grav.	Soda per cent.	Spec. grav.	Soda per cent.	Spec. grav.	Soda per cent.	Spec. grav.	Soda per cent.
1·00	0·00	1·12	11·10	1·22	20·66	1·32	29·96
1·02	2·07	1·14	12·81	1·24	22·58	1·34	31·67
1·04	4·02	1·16	14·73	1·26	24·47	1·35	32·40
1·06	5·89	1·18	16·73	1·28	26·33	1·36	33·08
1·08	7·69	1·20	18·71	1·30	28·16	1·38	34·41
1·00	9·43						

SODA-ALUM. See ALUM.

SODA, BIBORATE OF. See BORACIC ACID, and BORAX

SODA, BISULPHATE. $NaO.HO.2SO^3$ (**$NaHSO^4$**). This is obtained in the same manner as bisulphate of potash, with which it corresponds.

SODA, CARBONATE OF (*Kohlensaures Natron*, Ger.), is the 'soda' of commerce in various states, either crystallised, in lumps, or in a crude powder called 'soda-ash.' It exists in small quantities in certain mineral waters; as, for example, in those of Seltzer, Seydschutz, Carlsbad, and the volcanic springs of Iceland, especially the Geyser; it frequently occurs as an efflorescence in slender needles upon damp walls, being produced by the action of the lime upon the sea-salt present in the mortar. The mineral soda is the sesquicarbonate, to be afterwards described.

Of manufactured soda, the variety most anciently known is *barilla*, the incinerated ash of the *Salsola soda.* This plant is cultivated with great care by the Spaniards, especially in the vicinity of Alicant. The seed is sown in light low soils, which are embanked towards the sea-shore, and furnished with sluices, for admitting an occasional overflow of salt water. When the plants are ripe, the crop is cut down and dried; the seeds are rubbed out and preserved; the rest of the plant is burnt in rude furnaces, at a temperature just sufficient to cause the ashes to enter into a state of semi-fusion, so as to concrete on cooling into cellular masses comparatively compact. The most valuable variety of this article is called *sweet barilla.* It has a greyish-blue colour, and becomes covered with a saline efflorescence when exposed for some time to the air. It is hard and difficult to break; when applied to the tongue, it excites a pungent alkaline taste.

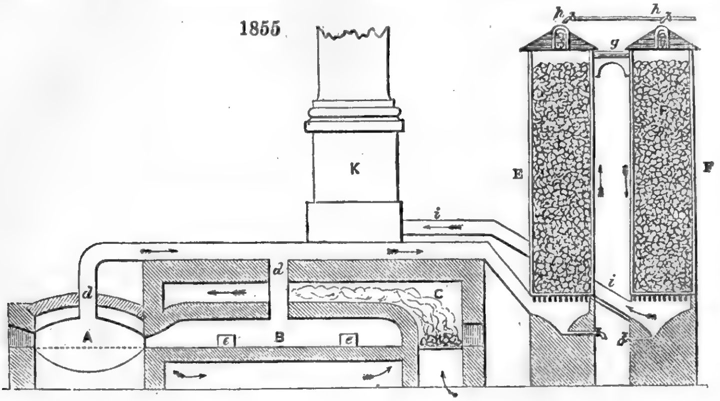
Another method of manufacturing crude soda, is by burning sea-weed into *kelp.* Formerly, very large revenues were derived by the proprietors of the shores of the Scottish islands and Highlands, from the incineration of sea-weeds by their tenants, who usually paid their rents in kelp; but since the tax has been taken off salt, and the manufacture of a crude soda from it has been generally established, the price of kelp has fallen low, its principal use being now to obtain iodine. See BARILLA, IODINE, KELP.

The crystals of soda carbonate, as well as the soda-ash of British commerce are now made altogether by the decomposition of sea-salt.

Soda-manufacture. The manufacture divides itself into three branches:—1. The conversion of sea-salt, or common salt (chloride of sodium), into sulphate of soda. 2. The decomposition of this sulphate into crude soda, called *black balls* by the workmen. 3. The purification of these balls, either into a dry white soda-ash or into crystals.

Preparation of Sulphate of Soda. The decomposition of common salt is effected by sulphuric acid in furnaces of which *fig.* 1855 is a section. A, the smaller of the two compartments which compose the furnace, is of cast iron; into this (*the decomposer*) from five to six hundred weight of common salt are introduced, and an equal weight of sulphuric acid, of specific gravity 1·6, is gradually mixed with it; a gentle heat being applied to the outside, enormous volumes of hydrochloric acid gas are disengaged, and pass off by the flue, *d*, to the condensing towers, E and F; these towers are filled with fragments of broken coke or stone, over which a continuous stream of water is caused to trickle slowly from *h h.* A steady current of air is drawn through the furnace and condensing towers, by connecting the first tower with the second, as represented at *g*, and the second tower with the main chimney, K, of the works. In the first bed of the furnace, about half of the common salt is decomposed, leaving a mixture of bisulphate of soda and common salt, which requires a greater heat for the expulsion of this latter portion of hydrochloric acid; for this purpose it is pushed through a door into the *roaster*, or second division, B, of the furnace.

1855



The reaction in the first bed of the furnace is represented as follows:—

$$\underbrace{2NaCl}_{\text{Common salt.}} + \underbrace{2HO.SO^3}_{\text{Sulphuric acid.}} = \underbrace{NaO.SO^3.\ HO.SO^3}_{\text{Bisulphate of soda.}} + \underbrace{HCl}_{\text{Hydrochloric acid.}} + \underbrace{NaCl.}_{\text{Common salt.}}$$

$$\mathbf{2NaCl + H^2{=}SO^4 = NaHSO^4 + HCl + NaCl}$$

By the higher temperature obtained in the second part of the furnace, the bisulphate of potash reacts on the undecomposed chloride of sodium, yielding neutral sulphate of soda and a fresh quantity of hydrochloric acid.

$$\underbrace{NaO.SO^3.\ HO.SO^3}_{\text{Bisulphate of soda.}} + \underbrace{NaCl}_{\text{Common salt.}} = \underbrace{2(NaO.SO^3)}_{\text{Sulphate of soda.}} + \underbrace{HCl.}_{\text{Hydrochloric acid.}}$$

$$\mathbf{NaHSO^4 + NaCl = Na^2SO^4 + HCl}$$

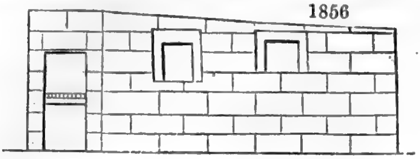
The hydrochloric acid gas, as it is liberated from B, passes off through the flue, *d*, and is carried on to the condensing towers. Heat is applied to the outside of the roaster, B; the smoke, C, circulating in separate flues around the chamber, in the direction indicated by the arrows, but never coming into contact with the salt-cake in B.

The process used at present in the Tyne district differs but little from that above described, with the exception that in the decomposition of the mixture of bisulphate of soda and common salt, in the second portion of the furnace, the smoke and products of combustion from the fire, are allowed to come in contact with the materials, and the hydrochloric acid which is then given off is carried into condensing towers filled with bricks over which water is continually slowly running, and the dilute hydrochloric acid, thus obtained, is used for the liberation of carbonic acid in the manufacture of bicarbonate of soda. The first part of the furnace is a circular metal pan, and the hydrochloric acid from this, being unmixed with smoke, &c., is condensed apart from the other.

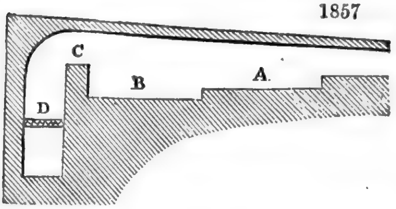
The next step in the manufacture is the decomposition of the sulphate of soda into sulphide of sodium, and its subsequent conversion into carbonate of soda. This is effected in the following manner:—The dry sulphate of soda, obtained by the process above described, is mixed with small coal and chalk, or limestone, in about the following proportions: sulphate of soda 3 parts, chalk 3½ parts, and coal 2 parts. It is necessary that these materials should be first separately ground, and sifted into a tolerably fine powder, and then carefully mixed, as a great deal depends on the attention to these points. The mixture is then subjected to heat in a reverberatory furnace, *figs.* 1856, 1857, 1858.

In the section *fig.* 1857, there are two hearths in one furnace, the one elevated above the level of the other by the thickness of a brick, or about three inches. A is the preparatory shelf, where the mixture to be decomposed is first laid in order to be thoroughly heated, so that when transferred to the lower or decomposing hearth, B, it may not essentially chill it, and throw back the operation. C is the fire-bridge, and D is the grate. In the horizontal section, or ground plan, *fig.* 1858, we see an opening in the front corresponding to each hearth. There is a door, as shown in the side view or elevation of the furnace, *fig.* 1856; and each door is shut by an square iron frame filled with a fire-tile or bricks, and suspended by a chain over a pulley fixed in any convenient place. (See COKE.) The workman, on pushing up the door lightly, makes it rise, because there is a counterweight at the other end of each chain, which balances the weight of the frame and bricks. In the ground plan, only one smoke-flue is shown; and this construction is preferred by many manufacturers; but others choose to have two flues, one from each shoulder, as at *a*, *b*; which two flues afterwards unite in one vertical chimney, from 25 to 40 feet high; because the draught of a soda furnace must be very sharp. Having sufficiently explained the construction of this improved furnace, we shall now proceed to describe the mode of making soda with it.

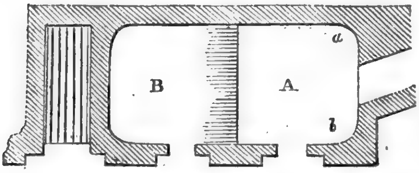
1856



1857



1858



The quantity of the mixture required for a charge depends, of course, on the size of the furnace. This charge must be shovelled in upon the hearth, A, or shelf of preparation (*fig.* 1857); and whenever it has become hot (the furnace having been previously brought to bright ignition), it is to be transferred to the decomposing hearth or laboratory, B, by an iron tool, shaped exactly like an oar, called *the spreader*. This tool has the flattened part from 2 to 3 feet long, and the round part, for laying hold of and working by, from 6 to 7 feet long. Two other tools are used: one, a rake, bent down with a garden hoe at the end; and another, a small shovel, consisting of a long iron rod terminated like a piece of iron plate, about 6 inches long, 4 broad, sharpened and tipped with steel, for cleaning the bottom of the hearth from adhering cakes or crusts. Whenever the charge is shoved by the sliding motion of the oar down upon the working hearth, a fresh charge should be thrown into the preparation shelf, and evenly spread over its surface.

The hot and partially-carbonised charge being also evenly spread upon the hearth, B, is to be left untouched for about ten minutes, during which time it becomes ignited, and begins to fuse upon the surface. A view may be taken of it through a peep-hole in the door, which should be shut immediately, in order to prevent the reduction of the temperature. When the mass is seen to be in a state of incipient fusion, the workman takes the oar and turns it over breadth by breadth in regular layers, till he has reversed the position of the whole mass, placing on the surface the particles which were formerly in contact with the hearth. Having done this, he immediately shuts the door, and lets the whole get another decomposing heat. After five or six minutes, jets of flame begin to issue from various parts of the pasty-consistenced mass. Now is the time to incorporate the materials together, turning and spreading by the oar, gathering them together by the rake, and then distributing them on the reverse part of the hearth; that is, the oar should transfer to the part next the fire-bridge the portion of the mass lying next the shelf, and *vice versâ*. The dexterous management of this transposition characterises a good soda-furnacer. A little practice and instruction will render this operation easy to a robust clever workman. After this transposition, incorporation, and spreading, the door may be shut again for a few minutes, to raise the heat for the finishing off. Lastly, the rake must be dexterously employed to mix, shift, spread, and incorporate. The jets, called *candles*, are very numerous, and bright at first; and whenever they begin to fade, the mass must be raked out into cast-iron moulds, placed under the door of the laboratory to receive the ignited paste.

One batch being thus worked off, the other, which has laid undisturbed on the shelf, is to be shoved down from A to B, and spread equally upon it, in order to be treated as above described. A third batch is then to be placed on the shelf.

The product thus obtained is called 'black balls,' which, of course, vary in their composition. The following is the composition, according to Richardson, of the Newcastle 'black balls,' from the balling furnaces:—

Carbonate of soda 9·89, hydrate of soda 25·64, sulphide of calcium 35·57, carbonate of lime 15·67, sulphate of soda 3·64, chloride of sodium 0·60, sulphide of iron 1·22, silicate of magnesia 0·88, carbon 4·28, sand 0·44, and water 2·17 = 100.

The *principal* changes which take place in this process may be represented by the following equations:—

$$\underbrace{NaO.SO^3}_{\text{Sulphate of soda.}} + \underbrace{4C}_{\text{Carbon.}} = \underbrace{NaS}_{\text{Sulphide of sodium.}} + \underbrace{4CO}_{\text{Carbonic oxide.}}$$

$$(\mathbf{Na^2SO^4} + \mathbf{2C^2} = \mathbf{Na^2S} + \mathbf{4CO}).$$

then—

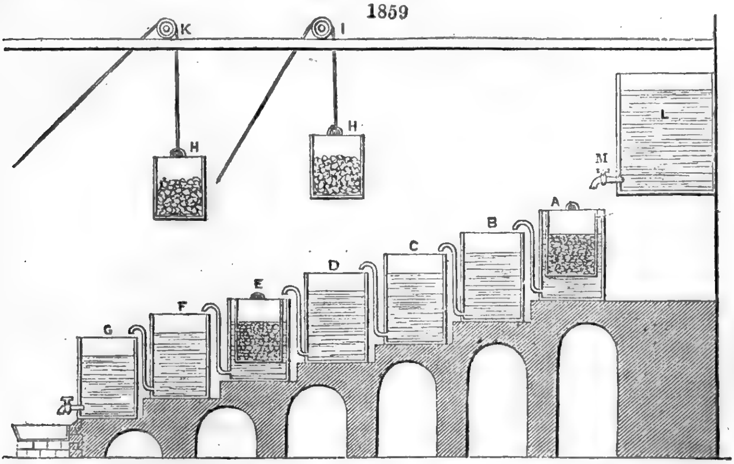
$$\underbrace{NaS}_{\text{Sulphide of sodium.}} + \underbrace{CaO.CO^2}_{\text{Chalk.}} = \underbrace{NaO.CO^2}_{\text{Carbonate of soda.}} + \underbrace{CaS}_{\text{Sulphide of calcium.}}$$

$$(\mathbf{Na^2S} + \mathbf{CaCO^3} = \mathbf{Na^2CO^3} + \mathbf{CaS}).$$

In the first place, the sulphate of soda is deoxidised by the coal, with the formation of sulphide of sodium and carbonic oxide, which latter takes fire and forms the 'candles,' above mentioned; in the next place, the sulphide of sodium and carbonate of lime (chalk) decompose each other, forming carbonate of soda and sulphide of calcium; and from the fact of some of the chalk being converted into caustic lime by the heat of the furnace, there is also formed by it some caustic soda; the sulphide of calcium itself is only sparingly soluble in water, but is rendered still less so by the excess of lime which is present, forming with it an oxysulphide, which is much less soluble than the sulphide of calcium alone.

This *black ball*, or *ball alkali*, is then treated with warm water to extract the soluble matters. This is effected in the district of Newcastle-on-Tyne in vessels, 8 or 10 feet square and 5 or 6 feet deep, furnished with false bottoms; the first waters are strong enough for boiling down, for getting 'yellow salt,' as it is termed; the after-washings, which are weaker, are used for fresh quantities of 'ball alkali.' Care must be taken not to use the water too hot, as the oxysulphide of calcium would be decomposed, and the liquor thus take up much sulphide of calcium.

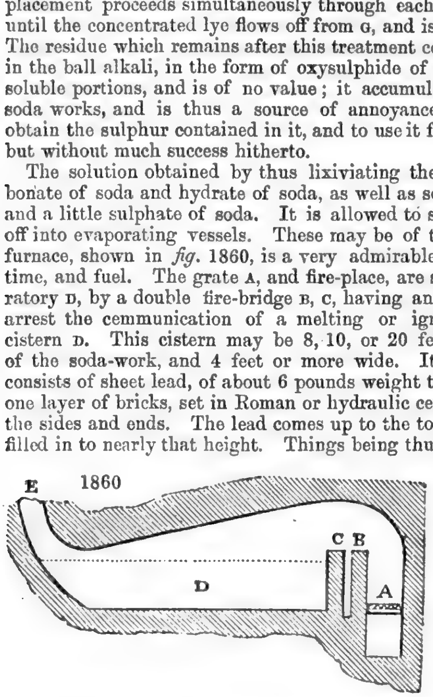
1859



An apparatus used in some places for lixiviating the black ball is shown in the accompanying drawing, *fig.* 1859. Its object is to extract the largest quantity of soluble matter with the smallest quantity of water. The black ball is placed in perforated sheet-iron vessels, H H, which can be raised or lowered into outer lixiviating vessels, also made of iron, by means of the cords and pulleys, I, K. When a charge is received from the furnace, it is introduced into the lowest vessels, G, where it is submitted to the dissolving action of a liquid already highly charged with alkali from digestion upon the black ash contained in the tanks above it; after a certain time, this charge is raised by the rope from G into the tank F, where it is submitted to a weaker liquid, and so on, successively. The alkali at each stage becomes more completely exhausted, and the residue is successively submitted to the action of weaker lye, till at length, in A, it is acted on by water only, supplied from the cistern, L. When fresh water is admitted from M, to the top of the vessel, A, as it is specifically lighter than the saline solution, it lies upon its surface, and gradually displaces the solution from A, through the bent tube, whilst the water takes its place; the liquid thus displaced from it, acts in like manner upon that contained in B; and this displacement proceeds simultaneously through each successive tier of the arrangement, until the concentrated lye flows off from G, and is transferred to the evaporating pans. The residue which remains after this treatment contains nearly all the sulphur present in the ball alkali, in the form of oxysulphide of calcium, together with the other insoluble portions, and is of no value; it accumulates to an immense extent in large soda works, and is thus a source of annoyance. Many trials have been made to obtain the sulphur contained in it, and to use it for the reproduction of sulphuric acid, but without much success hitherto.

The solution obtained by thus lixiviating the ball soda, contains principally carbonate of soda and hydrate of soda, as well as some sulphide and chloride of sodium, and a little sulphate of soda. It is allowed to settle; then the clear liquor is drawn off into evaporating vessels. These may be of two kinds. The surface-evaporating furnace, shown in *fig.* 1860, is a very admirable invention for economising vessels, time, and fuel. The grate A, and fire-place, are separated from the evaporating laboratory D, by a double fire-bridge B, C, having an interstitial space in the middle, to arrest the communication of a melting or igniting heat towards the lead-lined cistern D. This cistern may be 8, 10, or 20 feet long, according to the magnitude of the soda-work, and 4 feet or more wide. Its depth should be about 4 feet. It consists of sheet lead, of about 6 pounds weight to the square foot, and it is lined with one layer of bricks, set in Roman or hydraulic cement, both along the bottom and up the sides and ends. The lead comes up to the top of *c*, and the liquor, or lye, may be filled in to nearly that height. Things being thus arranged, a fire is kindled upon the grate A; the flame and hot air sweep along the surface of the liquor, raise its temperature there rapidly to the boiling point, and carry off the watery parts in vapour up the chimney E, which should be 15 or 20 feet high, to command a good draught. But, indeed, it will be most economical to build one high capacious chimney stack, as is now done at Glasgow, Manchester, and Newcastle, and to lead the flues of the several furnaces above described into it. In this evaporating furnace the heavier and stronger lye goes to the bottom, as well as the impurities, where they remain undisturbed. Whenever the liquor has attained to the density of 1·3, or thereby, it is pumped up into evaporating cast-iron pans, of a flattened somewhat hemispherical shape, and evaporated to dryness while being diligently stirred with an iron rake and iron scraper.

1860



This alkali gets partially carbonated by the above surface-evaporating furnace.

When pure carbonate is wanted, that dry mass must be mixed with its own bulk of ground coal, sawdust or charcoal, and thrown into a reverberatory furnace, like *fig.* 1857, but with the sole all upon one level. Here it must be exposed to a heat not exceeding 650° or 700° F.; that is, a little above the melting heat of lead; the only object being to volatilise the sulphur present in the mass, and carbonate the alkali. Now, it has been found, that if the heat be raised to distinct redness, the sulphur will not go off, but will continue in intimate union with the soda. This process is called *calking*, and the furnace is called a *calker furnace*. It may be 6 or 8 feet long, and 4 or 5 feet broad in the hearth, and requires only one door in its side, with a hanging iron frame filled with a fire-tile or bricks, as above described.

This carbonating process may be performed upon several cwts. of the impure soda, mixed with sawdust, at a time. It takes three or four hours to finish the desulphuration; and it must be carefully turned over by the oar and the rake, in order to burn the coal into carbonic acid, and to present the carbonic acid to the particles of caustic soda diffused through the mass, so that it may combine with them.

When the blue flames cease, and the saline matters become white, in the midst of the coaly matter, the batch may be considered as completed. It is raked out, and when cooled, lixiviated in great iron cisterns with false bottoms, covered with mats. The watery solution being drawn off clear by a plug-hole, is evaporated either to dryness, in hemispherical cast-iron pans, as above described, or only to such a strength that it shows a pellicle upon its surface, when it may be run off into crystallising cisterns of cast-iron or lead-lined wooden cisterns. The above dry carbonate is the best article for the glass manufacture.

Instead of this last process of roasting with sawdust, Gossage decomposes the sulphide of sodium present in the lye obtained from the ball soda, by means of the hydrated oxide of some metal, as of lead, thus forming sulphide of lead, and hydrate of soda; this is then converted into carbonate by passing a stream of carbonic acid through it. The precipitated sulphide of lead is decomposed by hydrochloric acid, thus generating sulphuretted hydrogen, which is burnt and converted into sulphuric acid; the lead is then converted again into hydrated oxide by means of lime. This process saves the trouble, time, and fuel used in evaporating to dryness twice as in the ordinary process.

Various attempts have been made to obtain processes which shall supersede the process above described, of manufacturing carbonate of soda from common salt.

Sulphate of iron, being a cheap article, has been heated with common salt, instead of using sulphuric acid; sulphate of soda is formed, and the chloride of iron, being volatile, passes away. By roasting iron or copper pyrites directly with chloride of sodium, sulphate of soda has been obtained, and it has been found possible by this means also to extract the metal from ores of copper or tin with advantage, which are otherwise too poor to work. Mr. Tilghman effects the decomposition of chloride of sodium by steam at a high temperature, in the presence of alumina. Precipitated alumina is made up into balls with chloride of sodium, and exposed to a current of steam in a reverberatory furnace strongly heated. Hydrochloric acid is expelled, and the alumina unites with the soda. When cold, this compound of alumina and soda is decomposed by a current of carbonic acid, and the carbonate of soda is dissolved, and thus separated from the alumina, which may be again used. Another process is that of MM. Schlœsing and Rolland. They dissolve the chloride of sodium in water, and then pass ammonia into it, and afterwards carbonic acid; bicarbonate of ammonia is first produced, and then double decomposition takes place; chloride of ammonium is formed, and the more sparingly soluble bicarbonate of soda is precipitated in crystalline grains; it is then separated from the liquid and pressed, to free it as much as possible from the chloride. This bicarbonate of soda is converted into the monocarbonate by heat, and the carbonic acid thus evolved is used again; the solution, from which the bicarbonate has separated, is boiled to drive off any ammonia that it may contain, as carbonate of ammonia, which is collected; the solution is then boiled with lime, which liberates the ammonia from the chloride of ammonium, and thus little loss is sustained.

There are three carbonates of soda:—

Monocarbonate. $NaO.CO^2 + 10HO$ ($\mathbf{Na^2CO^3 + 10H^2O}$). This is the salt which is obtained in the ordinary soda-manufacture. In the crystalline state, it generally contains ten equivalents of water of crystallisation, or sixty-three per cent., but has been obtained with only eight, five, and even one equivalent of water. It effloresces in a dry atmosphere, at the same time absorbing carbonic acid. It is very soluble in water, requiring only twice its weight of water at 60° for solution, and even melts in its own water of crystallisation when heated, and eventually by increase of temperature becomes anhydrous. It is generally found in commerce in large crystals, which belong to the oblique prismatic system. It is strongly alkaline, and acts on the skin, dissolving the outside cuticle. It is largely used in the manufacture of soap, glass, &c.

Sesquicarbonate. $2(NaO.CO^2),HO.CO^2$ ($\mathbf{2Na^2CO^3,H^2CO^3}$). This salt is frequently found native. See NATRON.

Bicarbonate. $NaO.CO^2,HO.CO^2$ ($\mathbf{NaHCO^3}$). This salt is found in some mineral waters, as those of Carlsbad and Seltzer; and is obtained from the waters of Vichy in large quantities.

It is prepared by saturating the monocarbonate with carbonic acid, for which purpose several methods are employed.

1. *By passing carbonic acid into a solution of the monocarbonate.* A cold saturated solution of the monocarbonate of soda is made, and carbonic acid obtained by the action of hydrochloric acid on marble or chalk, is passed into it; the bicarbonate forms and precipitates to a great extent, and is then collected, and pressed to remove as much of the adhering liquid as possible. A fresh portion of the

monocarbonate is dissolved in the mother-liquor, and the passage of carbonic acid through it repeated. By this method a pure bicarbonate is obtained, but the process is costly.

2. *By exposing solid monocarbonate of soda to an atmosphere of carbonic acid gas.* This is known as Smith's process. The crystals of the monocarbonate are placed on shelves, slightly inclined to allow the water to run off, in a large box, containing a perforated false bottom; carbonic acid is passed into this box under pressure, which latter is scarcely necessary, since the monocarbonate so rapidly absorbs the carbonic acid. When the gas ceases to be absorbed, the salt is taken out and dried by a *gentle* heat.

The crystals are found to have lost their water of crystallisation, and to have become opaque and porous, and a bicarbonate, still, however, retaining their original shape. These are ground between stones like flour, care being taken to avoid the evolution of much heat.

3. Its formation by the action of bicarbonate of ammonia has been already described.

Bicarbonate of soda crystallises in rectangular four-sided prisms, which require about ten parts of cold water to dissolve them, and if the solution be boiled, it loses carbonic acid, becoming first sesquicarbonate, and ultimately monocarbonate. As usually met with in commerce this salt is a white powder. Its taste is slightly alkaline. It is largely used in medicine, for making seidlitz powders, &c., but the salt generally found in the shops is only a sesquicarbonate, or a mixture of bicarbonate and sesquicarbonate.

The latest obtainable returns, show that the materials used on the Tyne in producing soda, and its alkaline manufactures, amount to 1,070,000 tons annually, consisting chiefly of pyrites, salt, chalk, coal, and manganese, the value of which is about 850,000*l.* This outlay produces:—

	Tons.		Tons.
Soda crystals	86,000	Caustic soda	3,720
Alkali	74,000	Epsom salts	590
Bicarbonate of soda	11,000	Glauber salts	20
Sulphate of copper	200	Oil of vitriol	9000
Sulphate of soda	2,400	Hyposulphite of soda	400
Bleaching powder	27,000	Muriatic acid	700
		Chloride of manganese	1,300
		Total tons.	216,330

Having an aggregrate value of 1,929,825*l.*

The products of the Lancashire chemical works are about the same, the total for all England being:—

	£
Raw materials	1,700,525
Manufactured article	3,813;604

The remarkable extension of the Alkali trade will be seen by the following statement of Exports:—

1858	1859	1860	1861	1862	1863
cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
1,618,289	2,029,761	2,049,582	1,420,327	2,095,249	2,137,015
1864	1865	1866	1867	1868	1869
cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
2,192,771	2,572,794	2,997,479	3,164,425	3,499,587	3,514,382
	1870	1871	1872	1873	
	cwts.	cwts.	cwts.	cwts.	
	3,853,393	4,176,667	4,453,068	4,754,425	

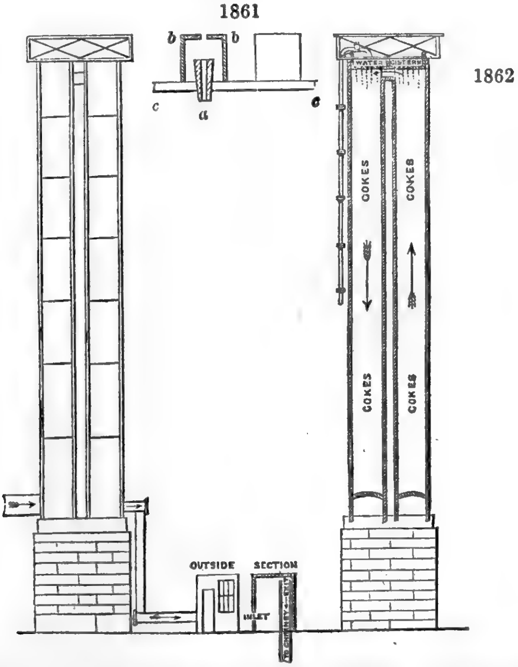
In the manufacture of carbonate of soda from common salt, there was always a considerable escape of muriatic acid, which was highly injurious to all surrounding vegetation. This led to the passing of a Bill to regulate this manufacture.

The Alkali Act of July 28, 1863, is 'An Act for the more effectual Condensation of Muriatic Acid Gas in Alkali Works.' An alkali work is defined by the Act to be 'every work for the manufacture of alkali, sulphate of soda, or sulphate of potash, in which muriatic acid is evolved.' It is required that 'every alkali work shall be carried on in such a manner as to secure the condensation to the satisfaction of the inspector, derived from his own examination or from that of a sub-inspector, of not less than 95 per centum of the muriatic acid gas evolved therein.'

Alkali Exported in 1873.

	Cwts.	Value
		£
To Russia	314,268	238,382
,, Sweden and Norway	126,551	70,116
,, Denmark	70,583	37,929
,, Germany	828,354	421,921
,, Holland	289,981	121,916
,, Belgium	199,643	120,982
,, France	110,959	61,589
,, Spain and Canaries	122,596	110,709
,, Italy	84,322	48,424
,, Austrian Territories	46,820	26,890
,, United States, Atlantic	2,124,017	1,371,506
,, ,, Pacific	25,314	20,632
,, Brazil	44,356	34,180
,, Australia	105,368	69,768
,, British North America	108,952	76,034
,, Other countries	143,341	98,028
Total	4,754,425	2,929,006

If we estimate the escape of muriatic acid gas at 1,000 tons per week before the passing of the Alkali Act, or at least before the introduction of the Alkali Bill into Parliament, we may be considered as taking a very moderate view of the question.



a, Wooden plug, with hole through the centre. *b* is a covering of earthenware which is nearly submerged, thus closing entirely the top of the tower when the water is admitted. *c c*, Bottom of water-cistern; the water passes through the side of *b b* close to *c c*, thus hermetically sealing the apertures. The floor of the water-cisterns at the top of each tower is covered with the wooden plugs as above and their coverings.

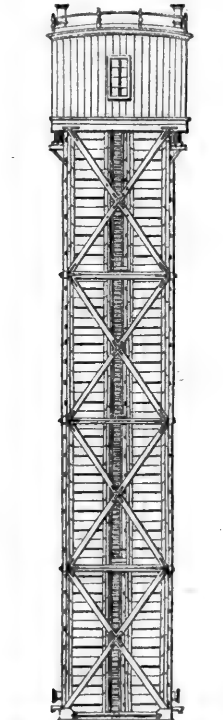
This supposes 2,324·96 to have been already condensed, and is a very favourable view of the case. The 1,000 tons left uncondensed are equal to 4,000 tons of 25 per cent. acid, and under one-third of the total amount evolved in the process of decomposing salt by sulphuric acid in the United Kingdom. This quantity amounts to 208,000 tons per annum.

Condensation is promoted by cold and by water mainly, but next to these we must add contact of surfaces and time.

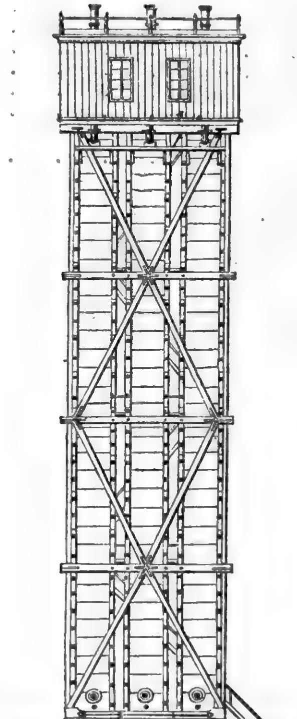
Air with a small quantity of muriatic acid in it will appear misty in moist weather, though the amount may be less than 0·003 per cent. It will pass rapidly through tubes well cooled and still appear misty, but let it pass between broken pieces of coke or through extremely narrow moist passages and it will be perfectly cleared. The floating particles too minute to fall seem to be filtered out as we filter fine precipitates. The mode of gaining extensive surface is chiefly by the use of coke in the towers.

Other modes have been adopted of filling the condensers. Fire-bricks are used in many cases, and especially at the lower part of condensers used for open roasters.

1863



1864



A *condenser* generally is a tower filled with moistened very porous or non-porous material, in pieces so large as to allow the passage of air and water through the interstices, and so small as to prevent that passage from being made without contact of the air or gases with the water and the solids present.

It is built generally in the form of a square tower. It is from 3 to 6 feet square equally from base to summit, and from 5 to 125 feet high. This height includes the pedestal and the cistern above the condensing portion of the tower. See *fig.* 1862.

1st. The simplest form of condenser allows the gas to enter below whilst the uncondensed portion escapes into the air at the top.

2nd. The uncondensed gases of the first tower may be sent into the top of the second tower, down which they may pass and thence either to the chimney or to a third and fourth tower.

3rd. A tower may be divided in two parts. The gases may pass up one side and down the other. This merely treats one as if it were two.

4th. The gases may pass up one tower and down earthenware pipes to the bottom of the second tower, up which they rise. By this method the gases pass up the towers only, and down tubes only.

5th. Condensers may be vessels of stone or of earthenware; when of stone they may be several feet in length, breadth, or depth. In these vessels a large amount of acid is frequently condensed before it passes to the towers. The gases may pass through several of these tanks.

6th. As the gases come from the roaster very hot, it is found of advantage to cool them before they enter the condenser. This is done by allowing them to pass along earthenware pipes for a great distance before entering the condensers. When these pipes are not used, the condenser is heated very highly and filled more or less with hot instead of cold water. This is the case sometimes to such an extent as to warm the whole tower. A great supply of water cools the tower but weakens the acid, and may even obstruct the passage of the gas too far.

7th. The first condenser is made large enough to condense all the gas, or several may be required. The greater part of the gas may be removed by one or more towers, leaving a small amount to be condensed by a post-condenser flushed with a great excess of water. This acid is not intended for use. Sometimes several condensers are connected with one post-condenser for a final washing. A greater amount of space and water being required to remove acid when it exists to the extent of only two or three per cent., the acid from these washings is often very dilute, sometimes so much as not to be sensible to the taste.

Figs. 1863 and 1864 are drawings in elevation of the fine towers at Messrs. Allhusen's. The stairs are entirely within the enclosure made by the six towers, and can be ascended with perfect safety. The chamber at the top contains the cistern and arrangements for the distribution of the water. At the very top are openings for the uncondensed gases. There are two rows of three towers, making six towers, for the pan-gases.

SODA FELSPAR. Usually called *Albite.* See FELSPAR.

SODA, HYPOCHLORITE OF. NaO.ClO (**NaClO**). This is obtained in the same manner as hypochlorite of lime, or by decomposing a solution of this latter by carbonate of soda. Its uses are the same as those of the hypochlorite of lime.

SODA, HYPOSULPHITE OF. This is now largely prepared for photographic purposes. See HYPOSULPHITE of SODA.

SODA, NITRATE, OF. NaO,NO^5 ($\mathbf{NaNO^3}$). Syn. *cubic nitre; Chile saltpetre.* (*Nitrate de soude*, Fr.; *Würfelsalpeter*, Ger.) This important salt is found native in immense quantities in Chili and Peru. It is, in some parts, found in beds of several feet in thickness. As found in nature it is tolerably pure, the principal impurities being chlorine, sulphuric acid, and lime. Nitrate of soda can be formed artificially by saturating nitric acid with soda or its carbonate, and evaporating the solution.

Nitrate of soda is extensively and economically employed as a source of nitric acid. It is also used for the purpose of being converted by double decomposition with chloride of potassium into nitrate of potash. (See NITRATE OF POTASH.) It is employed as a manure.

A good sample of nitrate of soda should not contain more than two per cent. of chloride of sodium. The nitric acid may be determined by the process described under NITRATE OF POTASH.

Nitrate of soda is not applicable for the preparation of gunpowder or fireworks. partly in consequence of its tendency to attract moisture from the air, and partly owing to the fact that mixtures made in imitation of gunpowder, but having nitrate of soda in place of nitrate of potash. It has, however, been prepared and used for blasting-powder, with some apparent advantage. See CUBIC NITRE.

SODA, NITRITE OF. NaO,NO^3 ($\mathbf{NaNO^2}$). This salt is not unfrequently employed as a source of nitrous acid, especially in researches on the volatile organic bases. Nitrite of soda possesses some advantages over nitrite of potash, owing to the comparative ease with which it is prepared.

SODA, PHOSPHATES OF. Several of these are known, but are not important in the arts. The principal are the normal tribasic phosphate, the well-known rhombic phosphate, the pyrophosphate, and the metaphosphate of soda.

SODA, SULPHATE OF. $NaO.SO^3+10HO$ ($\mathbf{Na^2SO^4+10H^2O}$). This salt is obtained as a residue in several chemical processes, as in the manufacture of hydrochloric and nitric acids, &c., but owing to the enormous quantity used in the manufacture of carbonate of soda, it is made purposely as described under SODA, CARBONATE OF. It is known as *Glauber's salt,* and has been found native near Madrid, nearly pure, deposited at the bottom of some saline lakes, in anhydrous octahedra, called *Thénardite*, and also combined with sulphate of lime, as *Glauberite*.

It crystallises in oblique rhombic prisms which belong to the oblique prismatic system. Its taste is saline, and bitterish. It is very efflorescent, and loses all its ten equivalents of water by mere exposure to the atmosphere, at common temperatures.

SODA, SULPHITE OF. $NaO.SO^2 + 10HO$ (**$Na^2SO^3 + 10H^2O$**). This salt is prepared largely for removing the last traces of chlorine from the bleached pulp obtained in the manufacture of paper, and is hence called *antichlore*.

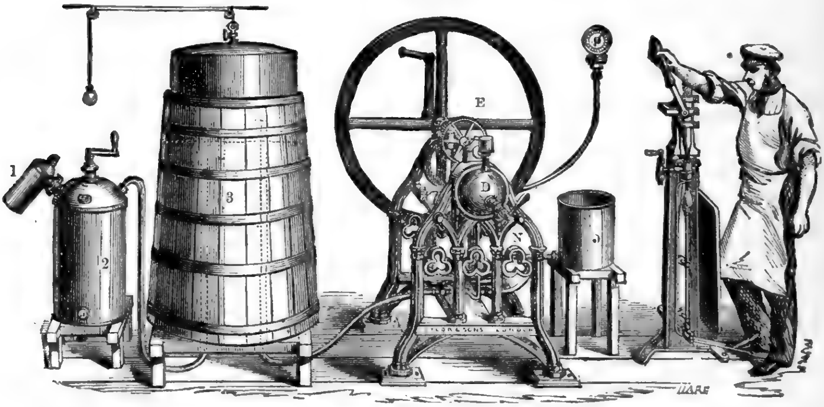
It is prepared by passing sulphurous acid gas through a solution of carbonate of soda, or on the large scale, by passing sulphurous acid gas, obtained by burning sulphur in the air, over crystals of carbonate of soda. It crystallises in oblique prisms, and is efflorescent, like the sulphate of soda, which it much resembles. Its taste is sulphurous, and it possesses a slight alkaline reaction.

A *bisulphite of soda* also exists, which forms irregular opaque crystals.

SODA-WATER. A favourite beverage, formed by super-saturating a solution of carbonate of soda with carbonic acid, produced under considerable pressure.

The accompanying wood-engraving represents the improved arrangements of the soda-water machine, as fixed for use, manufactured by Messrs. J. Tylor and Sons of 2 Newgate Street, London.

1865



To use this machine, it is necessary to fill the solution-pan o, with solution of soda, about one ounce of bicarbonate of soda to 2 gallons of water. Usually this solution is made in a large cistern of slate, or wood lined with lead, from which it is conveyed to the solution-pan, by means of a pipe and tap. The gasometer-tub (3) is filled with water up to a constant level, above which the opening of the pipe coming from the solution-pan is kept, while the other pipe, connected with the generator 2, is kept well under the water. The bell of the gasometer being down, about 14 lbs. of powdered whiting is mixed with water, to the consistency of cream, and poured into the generator (2) till it is about two-thirds full, when it is carefully closed. Next screw the leaden acid bottle (1) on to the generator. Take off the small cap on the top of bottle, and put in about a quart of diluted sulphuric acid—half acid and half water—and replace the cap. This should be mixed in an open vessel. Muriatic or nitric acid may be used, if sulphuric acid cannot be obtained. Swing the bottle slightly round, causing a little acid to fall into the whiting and water, at the same time turning round the agitator, the handle of which is on the top of the generator. As soon as the acid is mixed with the whiting and water, gas is generated and passes up the pipe into the rising bell, which it elevates by its pressure. The end of the other pipe is turned down below the surface of the water, so that the gas passing through it may become cooled and purified. The operation of making the gas should be conducted slowly, the acid bottle being so moved that only a small quantity of acid falls into the generator at a time, otherwise the gas would be generated too quickly, and throw the whiting and water into the pipe, and probably injure the generator.

When the addition of acid and the turning of the agitator fails to produce more gas, then the whiting is exhausted, and must be removed. It is important that this should be done after each time of using, before the whiting sets hard, or there will be a difficulty in getting it out, and a liability of straining or breaking the fan of the agitator.

The first time of using there will be a quantity of air in the bell, which is discharged by opening the cock. When the gas has a pungent smell it is fit for use.

The gas-tap and water-tap are provided with index-plates, which regulate the supply of gas and water to the pump of machine; they must be partly opened or closed by the person working the machine to suit the requirements. The machine must not be worked with the water-tap open alone. The machine being set to work the gas is drawn down the pipe, which stands above the level of the water, through the other pipe, and is forced into the condenser (D), where an agitator, worked by the spur-wheel (E), revolving rapidly, mixes it with the water which is drawn from the solution-pan O in like manner. When the pressure is up the safety valve will lift, and soda-water may be bottled from the nose (N). A pressure gauge may be recommended as very useful in enabling the person working the machine to keep the pressure uniform.

SODIUM. (*Symb.* Na; *At. Wt.* 23.) This metal was discovered by Sir H. Davy, almost immediately after potassium, and by the same means, viz., by exposing a piece of moistened hydrate of soda to the action of a powerful voltaic battery, the alkali being placed between a pair of platinum plates connected with the battery.

By this process only very small quantities can be obtained, but processes have since been devised which provide it in almost any quantity, and since the demand for sodium in the manufacture of aluminium by Wöhler's process, principally by the exertions of M. C. St.-Claire Deville, the cost of it has been considerably diminished. The process now adopted is the same as that for obtaining potassium. An intimate mixture of carbonate of soda and charcoal is made by igniting in a covered crucible a salt of soda containing an organic acid, as the acetate of soda, &c., or by melting ordinary carbonate of soda in its water of crystallisation and mixing with it, while liquid, finely-divided charcoal, and evaporating to dryness; this mixture is mixed with some lumps of charcoal and placed in a retort, which is generally made of malleable iron, but owing to the difficulty of getting them sufficiently large, earthenware or fire-clay retorts have been used with success, and sometimes these are lined with or contain a trough of malleable iron. These retorts are so placed in a furnace that they are uniformly kept at a heat approaching to whiteness.

The principal reaction which takes place in the retort, is the reduction of the soda by the charcoal, which is thus converted into carbonic oxide, which escapes through an aperture in the receiver made on purpose.

Sodium is a silver-white metal, very much resembling potassium in every respect; it is so soft at ordinary temperatures that it may be easily cut with a knife or pressed between the finger and thumb; it melts at 194° Fahr., and oxidises rapidly in the air, though not so rapidly as potassium. Its sp. gr. is 0·972. When placed upon the surface of cold water it decomposes it with violence, but does not ignite the hydrogen which is liberated, unless the motion of the sodium be restrained, when the cooling effect is much less. When a few drops of water are added to sodium the hydrogen liberated immediately inflames, and such is also the case if it be put on hot water; when burning it produces a yellow flame, and yields a solution of soda. The principal use of sodium is, as before stated, in the manufacture of aluminium, which is now carried on to a considerable extent.

SODIUM, BROMIDE OF. This salt resembles the bromide of potassium.

SODIUM, CHLORIDE OF. See SALT.

SODIUM, IODIDE OF. This exists in considerable proportion in the ash of burnt sea-weeds. See KELP.

SODIUM, OXIDES OF. When sodium is burnt in oxygen gas or in air, two different oxides are produced, viz. the protoxide and binoxide. These oxides very much resemble the corresponding oxides of potassium.

SODIUM, SULPHIDES OF. Several of these are known, resembling the corresponding salts of potassium, but they are of no importance in the arts.

SOJA. The legumes of *Soja hispida* are used in the preparation of soy, and are imported to this country from India.

SOLANINE. A poisonous alkaloïd of doubtful constitution, contained in various plants of the species *Solanum*, as *S. nigrum*, *S. Dulcamara*, and in the potato (*S. tuberosum*). It is remarkable that in the shoots of potatoes which have sprouted in dark cellars the quantity of solanine is greater than in the shoots which have germinated normally. Solanine requires reinvestigation.

SOLAZZI JUICE. A name given to the best kind of Spanish liquorice, Solazzi being the maker's name. See LIQUORICE.

SOLDERING. The process of uniting together pieces of metal, by the interposition of a fusible alloy, which is called either soft or hard solder, according as its fusing point is low or high. One process is called by its inventor, M. de Richemont, *autogenous*, because it takes place by the fusion of the two edges of the metals themselves, without interposing another metallic alloy, as a bond of union. See Autogenous Soldering.

SOLDERS. Alloys which are employed for the purpose of joining together metals are so called. They are of various kinds, being generally distinguished into hard and soft. Upon the authority of Holtzappfel, the following receipts for solder are given. and these have been adopted, because, after a long and particular inquiry in the workshops, we learn that they are regarded as very superior to any others recommended:—

Pewterers' Solder. (*a*) 2 Bismuth, 4 lead, 3 tin. (*b*) 1 Bismuth, 1 lead, 2 tin.

Soft Spelter Solder. Equal parts of copper and zinc.

Coarse Plumbers' Solder. (*a*) 1 tin, 3 lead, melts at about 500° Fahr. (*b*) 2 tin, 1 lead, melts at about 360° Fahr.

Spelter Solder. 12 ozs. of zinc to 16 ozs. of copper.

SOLFERINO. See Aniline Red.

SOMBRERITE. An impure phosphate of lime, from the island of Sombrero, in the West Indies. It appears to have been produced by the action of water, which having filtered through guano, has acted on a coral rock, whereby the carbonate of lime of the coral-limestone has been converted into a phosphate.

SOORANJEE, called also *Morindin*, a dye-drug prepared from the root of the *Morinda citrifolia*. See Crookes's 'Practical Handbook of Dyeing and Calico-Printing.' See Aal.

SOOT (*Noir de fumée, Suie*, Fr.; *Russ, Flatterruss*, Ger.) is the pulverulent charcoal condensed from the smoke of wood or coal-fuel.

SORBIC ACID is the same with malic acid. See Malic Acid.

SORGHO. The name of a species of grass, the *Holcus* or *Sorghum saccharatum*. See Broom Corn.

SORGHUM. A sugar-yielding grass has been introduced into the south of Europe and North America, the cultivation of which has extended with wonderful rapidity in the United States, in regions far to the north of those adapted to the sugar-cane. The seeds of this plant are a good grain, similar to the Durra so extensively cultivated in the East Indies and in Africa. The Durra (*Sorghum vulgare*), sorgho, or Indian millet, may be said to be the principal corn-plant of Africa; and the sugar-grass, or shaloo (*Sorghum saccharatum*) may be regarded as a superior kind of Durra.

The sugar-grass was introduced into Europe in 1851 by the Count de Montigny, the French Consul at Shanghai, who sent a package of seed to the Geographical Society of Paris, only one seed of which germinated, and from this plant a small quantity of ripe seed was produced; for eight hundred of which Messrs. Vilmorin, Andrieux, and Co. seed-merchants in Paris, paid eight hundred francs. Another portion of the same crop passed into the hands of the Count de Beauregard, and from these sources this seed was distributed over Europe and to America in 1857. Two years later, Mr. Wray took seeds from Africa to America, and two classes are now recognised there: the Chinese, or *sorgo*, and the African, or *Imphee*. The juice is expressed by mills, of which there are many kinds in use, wrought either by steam, water, or horses. The juice, as obtained from the mill, contains many impurities; dust and earth, small fragments of cane, and green vegetable-matter; these are in part removed by filtering through a straw filter, but more completely by skimming during the process of boiling; the syrup thus obtained is of a very good quality. The processes employed in procuring sugar from the sugar-cane in tropical countries are equally applicable in the case of the sugar-grass.

SOVEREIGN. The sovereign is the standard of value in Great Britain, and its weight is determined by the law that twenty pounds troy weight of standard gold shall be coined into 934½ sovereigns. To obtain the exact weight of one sovereign, reduce the pounds to grains and divide by the number of coins. A sovereign is thus found to weigh 123·2744783306581059 grains, and as it is usual to deliver the coin to the Bank in journey weights of 701 sovereigns, each journey should weigh, if it be standard work, 180·0321027287319442215 ounces; and a million sovereigns should weigh 256821·8298555377 troy ounces, in round numbers about 7·8618 tons.—G.F.A.

SOY is a liquid condiment, or sauce, imported chiefly from China. It is prepared with a species of white haricots, wheat-flour, common salt, and water; in the proportions respectively of 50, 60, 50, and 250 pounds. The haricots are washed, and boiled in water till they become so soft as to yield to the fingers. They are then laid in a flat dish to cool, and kneaded along with the flour, a little of the hot water of the decoction being added from time to time. This dough is next spread an inch or an inch and a half thick upon the flat vessels (made of thin staves of bamboo), and when it becomes hot and mouldy, in two or three days, the cover is raised upon bits of stick, to give free access of air. If a rancid odour is exhaled, and the mass grows green, the process goes on well; but if it grows black, it must be more freely exposed to the air. As soon as all the surface is covered with green mouldiness, which usually happens in eight or ten days, the cover is removed, and the matter is placed in the sunshine for several days. When it has become as hard as a stone, it is cut into small fragments, thrown into an earthen vessel, and covered with the 250 pounds of water having the salt dissolved in it. The whole is stirred together, and the height at which the water stands is noted. The vessel being placed in the sun, its contents are stirred up every morning and evening; and a cover is applied at night to keep it warm and to exclude rain. The more powerful the sun the sooner the soy will be completed; but it generally requires two or three of the hottest summer months. As the mass diminishes by evaporation, well-water is added; and the digestion is continued till the salt-water has dissolved the whole of the flour and the haricots; after which the vessel is left in the sun for a few days, as the good quality of the soy depends on the completeness of the solution, which is promoted by regular stirring. When it has at length assumed an oily appearance, it is poured into bags, and strained. The clear black liquid is the soy, ready for use.

SPANISH GRASS. See ESPARTO and PAPER.

SPAR, HEAVY or **PONDEROUS.** Sulphate of baryta. See BARYTA.

SPARRY IRON ORE, or **SPATHIC IRON.** (Syn. *Chalybite, Siderite, Siderose, Brown Spar,* &c.) Spathose iron ore has been largely worked on the Brendon Hills, in Somersetshire, and it is also found on Exmoor, and in Perranzabuloe, and at the iron mines on the north coast of Cornwall. It also occurs at Weardale in Durham. See IRON.

SPECIFIC GRAVITY designates the relative weight of different bodies under the same bulk: thus a cubic foot of water weighs 1,000 ounces avoirdupois; a cubic foot of coal, 1,350; a cubic foot of cast iron, 7,280; a cubic foot of silver, 10,400; and a cubic foot of pure gold, 19,200: numbers which represent the specific gravities of the respective substances, compared with water = 1,000. See GRAVITY, SPECIFIC.

SPECTRUM, *Solar* or *Prismatic.* If a pencil of solar light is admitted through a small hole, into a dark room, and allowed to fall upon the edge of a prism, a beautifully-coloured flame-like image is formed upon the opposite wall; the order of colours being red, orange, yellow, green, blue, indigo, and violet, the red being the least refrangible ray, and the violet the most so of the ordinary visible rays. Careful examination proves the yellow ray to be the most luminous; the red ray the most calorific ray; and the violet to possess the most energetic chemical power. Heat-rays, invisible under ordinary conditions exist below the red band; some of them having peculiar powers, are known as the parathermic rays; and chemical rays extend, with much power, far beyond the violet end of the visible spectrum. Luminous rays are also rendered visible at the most refrangible end of the spectrum by throwing the spectral image into a solution of sulphate of quinine, or on a piece of uranium glass, and some other substances; these are called the *fluorescent* rays. With this brief description of the Newtonian spectrum, as it is often called, (Sir Isaac Newton, being the first who investigated its striking phenomena) our readers must be satisfied. The practical applications of our knowledge form the subject of the next article.

SPECTRUM ANALYSIS. Dr. Wollaston was the first who observed the existence of non-luminous spaces or dark lines in the solar spectrum. Dr. Ritchie proved that these lines were dependent on absorption, and showed how they could be *increased in visible numbers by artificial means.* Fraunhofer, however, was the first to make a full investigation of them, and to publish a map of them; hence they have been generally called Fraunhofer's Lines.

These lines are of so fixed a character in relation to the coloured bands of the spectrum, that if it is desired to indicate with great precision any special rays of the spectrum, they are referred to by letters or numbers. The position the lines occupy have been determined by a careful examination of the map of Fraunhofer, and the very complete delineation of those lines published in the 'Philosophical Transactions' for 1859, by Sir David Brewster and Dr. Gladstone. Fraunhofer laid down on his map 354 lines, but Sir David Brewster says: 'In the delineations which I have executed, the spectrum is divided into more than 2,000 visible and easily recognised portions, separated from each other by lines more or less marked.'

The origin of these dark lines,—spaces in which there is no light,—can scarcely be said to be yet satisfactorily resolved. Fraunhofer, and others following him, thought that the light emitted from the photosphere was, from the first, deficient in those rays, or that they were lost, either by absorption in passing through the solar atmosphere, or obtained possibly in passing through that of the earth. Ångström, who also discovered many *bright lines* in the spectra from artificial lights, advanced some highly philosophical views in 1855. The dark lines of the solar spectrum, and the bright ones observable in the spectra obtained from artificial lights, were investigated by Professor Wheatstone, Dr. W. A. Miller, Mr. Fox Talbot and Sir John Herschel. These investigators proved that the spectra obtained from the light emitted from incandescent mineral bodies differ from that obtained from the sun; that the lines from artificial sources of light are, in many cases, peculiar; and that, in the majority of instances, *bright lines* appear to take their place. So rigidly exact were the positions and characters of the lines obtained from differently-coloured flames, that both Wheatstone and Miller suggested the adoption of spectral or prismatic analysis, as a means of determining the presence of exceedingly minute quantities of any substance. The more recent investigation of Bunsen and Kirchoff have, from their high interest, again drawn attention to this subject. These lines have been employed in the analysis of the solid mass of the sun itself; and the extreme delicacy of the indications is proved from the discovery of two new metallic bodies, one called *Cæsium* (meaning bluish-grey), and the other *Rubidium* (from the Latin *rubidus*, which was used to express the darkest red colour), which existed in infinitesimally small quantities in some mineral waters of Germany. *Thallium* was afterwards discovered by Mr. W. Crookes, and *Indium* by Professor Richter, by means of the spectrum. To render the phenomena, and the hypothesis involved, intelligible within the short space which can be given to the subject to those who may not have studied it, it is necessary to recapitulate, and enter a little into detail. The image produced by decomposing a white sunbeam consists of certain brilliantly-coloured rays, but those rays are crossed by spaces giving no light. The dark lines are always found in the same places in the solar spectrum, but they vary in number under different aspects of the sun and varying conditions of the earth's atmosphere. When the sun shines in its meridian splendour from a clear sky, the number of dark lines is slightly different from those observed when the sun, being near the horizon, has to penetrate a greater depth of atmosphere. 'It is,' says Dr. Gladstone, 'a most beautiful and striking sight to observe the gradual appearance of those characteristic lines as the sun descends towards the horizon,' proving that some of these non-luminous spaces are due to terrestrial atmospheric absorptions. To quote again the same authority: 'That the earth's atmosphere has much to do with the manifestations of those lines, is beyond all question, and the analogy' (alluding to some very striking experiments made by Dr. Miller) 'of such gases as nitrous acid or bromine vapour, *suggests the idea that they may originate wholly in the air that encircles our globe.*' The spectra, obtained from some artificial sources of light, exhibit the coloured rays shading one into the other; while those produced by some others consist of a series of *luminous bands*, separated by dark spaces; and *these luminous bands are frequently found to coincide with the dark lines of the solar spectrum.* Dr. W. A. Miller observed that an intense yellow ray observable in the spectra, obtained from the flames coloured with soda, lime, strontia, baryta, zinc, iron, and platinum, and, according to Ångström, in the electric light of *every metal burnt* by him, had the same refrangibility as the line D in the solar spectrum.

Pyrotechnic displays will have made the least scientific of our readers acquainted with the fact, that we may, by burning certain mineral substances, produce very intensely-coloured lights. Soda, or common culinary salt, gives a monochromatic yellow; strontia produces the red fires of our theatres; barytes, the pale green of ghost scenes; copper burns with a green flame, iron with a yellow-brown one, and lithium with a brilliant crimson. Now, if these flames be examined through a prism, or if a concentrated pencil from those artificial sources of coloured light be passed through one, we obtain well-marked spectral images.

The next step in the process of the investigation instructs us in the fact, that the vapours producing those coloured flames are opaque in their own rays. That is to say, if we produce a yellow soda-flame, and from it obtain a spectrum showing the peculiar soda lines in their bright yellow colour, and then impregnate the air with some soda-vapour, by volatilising soda between the flame and the spectrum, the *bright yellow line* becomes at once *a black line.* This holds true for all the substances which have yet been examined. The coloured bright lines are converted into dark lines, if the rays from the coloured flames are made to permeate vapours of the same constitution as those which produced the particular spectrum under examination.

Kirchoff and Bunsen lay great stress upon the sodium spectrum, as proving the extreme delicacy of this mode of analysis. The yellow line, the only one seen, is coincident with the dark line D of Fraunhofer. This beautiful bright yellow line is observable when less than 1-20,000,000th of a part of soda-vapour is mixed with air. From the circumstance of the air of these islands having almost always some saline matter floating in it, the yellow line of the sodium spectrum is rarely absent. The lithium spectrum gives two sharply-defined lines: one a bright red, the other a yellow one, the former apparently corresponding with line five between B and

C of Brewster's spectrum; it is not easy to determine accurately with which of the dark lines this yellow line is coincident. Strontium gives six red, one orange, and one blue line. Calcium and its salts, a bright green line, an intensely bright orange line, and the paler intermediate bands. Barium gives well-defined green lines, some yellow lines, varying in intensity, an orange line, and indications of red.

Incandescent gases and vapours give off light of certain definite degrees of refrangibility, or they furnish spectra consisting of certain fixed lines; and those incandescent gases or vapours absorb light of the same degree of refrangibility as that which they emit. This is (reasoning by analogy) only the expression in relation to *light* of the celebrated statement made in regard to *sound, that a body absorbs all the oscillations which it can propagate.*

Spectrum analysis has been applied with success to determine the moment when in the process of making steel by the Bessemer process the whole of the carbon is exhausted. For a full account of Spectrum Analysis, see Watts's 'Dictionary of Chemistry.'

SPECULUM METAL. The metal employed in the mirrors of reflecting telescopes. The late Earl of Rosse, who was eminently successful in the production and polishing of large specula, says, in his paper published in the *Transactions of the Royal Society*, 'Tin and copper, the materials employed by Newton in the first reflecting telescope, are preferable to any other with which I am acquainted, the best proportions being 4 atoms of copper to one of tin, in fact, 126·4 parts of copper to 58·9 of tin.'

Mr. Ross remarks that when the alloy for speculum metal is perfect, it should be white, glassy, and flaky. Copper in excess imparts a reddish tinge, and when tin is in excess the fracture is granulated and less white. Mr. Ross pours the melted tin into the copper when it is at the lowest temperature at which a mixture by stirring can be effected; then he pours the metal into an ingot, and, to complete the combination, remelts it in the most gradual manner, by putting the metal into the furnace almost as soon as the fire is lighted. Trial is made of a small portion taken from the pot immediately prior to pouring.

SPEISS. A compound of nickel, arsenic, and sulphur, containing small quantities of cobalt, copper, and antimony; it is found at the bottom of crucibles in which smalt is manufactured. See COBALT.

SPELTER or **SPELTRUM.** See ZINC.

SPERMACETI; the *Cetine* of Chevreul. In certain species of the *cachalot* whale, as the *Physeter macrocephalus*, and the *tursio*, *microps*, and *orthodon*, as also the *Delphinus edentulus*, the fat of some parts of their bodies contains a peculiar substance, called spermaceti. The head is the principal part from whence it is obtained. In the right side of the nose and upper surface of the head of the whale, is a triangular-shaped cavity, called by the whaler's, 'the case.' Into this the whalers make an opening, and take out the liquid contents (oil and spermaceti) by a bucket.

The dense mass of cellular tissue beneath the case and nostril, and which is technically called the 'junk," also contains spermaceti, with which and oil its tissue is infiltrated. The spermaceti from the *case* is carefully boiled alone and placed in separate casks, when it is called 'head matter.' This 'head matter' consists of spermaceti and oil. For the purpose of separating the spermaceti from the oil, it is cooled, when the spermaceti congeals, and is separated by being thrown into large filter bags, when the oil filters through, leaving the spermaceti behind; the solid thus obtained is subjected to compression in hair-bags, placed in an hydraulic press. It is then melted in water, and the impurities skimmed off. Then it is remelted in a weak solution of potash to remove the last particles of oil, washed in water, and fused in a tub by the agency of steam, laded into tin pans, and allowed slowly to cool, when it forms a white, semi-transparent, brittle, lamellar, crystalline mass. Commercial spermaceti usually contains a minute portion of sperm oil, which may be removed by boiling with alcohol; the spermaceti dissolves and again separates on cooling, in order to obtain it perfectly pure, this process must be repeated until the alcohol separates no more oil.

When absolutely pure, spermaceti is a white laminated substance, without taste, and most odourless, and in this case it is called *cetine.* By the addition of a few drops of alcohol or almond oil, it may be powdered. At 60° its sp. gr. is 0·943. It melts at 120°, and at 670° may be sublimed unchanged. It is insoluble in water, slightly soluble in alcohol, and much more so in ether; it is also soluble in the fatty and volatile oils, and if the solution be saturated when hot, the greater part of the spermaceti separates on cooling.

Spermaceti is only saponified with difficulty, in which process it is separated into two distinct substances: one, $C^{32}H^{34}O^{2}$ ($\mathbf{C}^{16}\mathbf{H}^{34}\mathbf{O}$), belonging to the series of alcohols, is called *cetylic* (*ethalic*) *alcohol*; and the other *cetylic* (*ethalic*) *acid*, $C^{32}H^{32}O^{4}$ ($\mathbf{C}\ {}^{6}\mathbf{H}^{32}\mathbf{O}^{2}$);

the first is a crystallisable fat, whose melting point is nearly the same as that of spermaceti itself, but it is much more soluble in alcohol; it is readily sublimed without decomposition. Cetylic acid stands to cetylic alcohol in the same relation as acetic acid to ordinary alcohol, and may be actually procured from it by oxidation. It resembles in many respects margaric acid. By oxidation by nitric acid spermaceti yields a large quantity of succinic acid.

Spermaceti is a cetylate of oxide of cetyl, and represents in the cetyl series the acetic ether of the common alcohol series. It may also be regarded as a palmitate of cetyl.

SPERM WHALE. *Physeter macrocephalus.* The animal inhabiting the Pacific and Indian Oceans which produces the sperm oil and spermaceti.

SPHENE. A compound of titanate and silicate of lime. See Titanium.

SPHEROIDAL STATE. The name given by Boutigny to the condition assumed by water when projected upon red-hot plates or into red-hot vessels. The fluid gathers into a spheroïdal drop, moving with a quick intestinal motion, but under this condition the temperature never rises to the boiling point. See Evaporation.

SPICES. See the separate articles on different kinds of spice.

The Spices imported in 1873 *and* 1874 *of which we have returns are the following:*

	1873		1874	
	Quantities	Value	Quantities	Value
Cinnamon . . . . lbs.	1,078.753	116,144	1,204,622	129,161
Ginger (raw) . . . cwts.	36,363	97,548	38,750	117,987
Pepper . . . . lbs.	26,324,828	818,437	19,596,843	563,896
Unenumerated . . . „	6,601,393	229,958	...	...

SPIEGELEISEN. A term applied to a particular variety of highly carburised pig-iron, usually containing a proportion of manganese. It is produced when smelting ores containing iron and manganese, under conditions which, with ordinary ores, would produce grey iron; that is with a large proportion of fuel to charge, very basic slags from the use of a large quantity of flux, and dense and hot blast. The name is derived from the largely facetted structure of the fracture, which resembles plates of glass. The structure is developed by cooling the iron under the slag, and is not indicative of the proportion of manganese. The amount of carbon is a maximum of 6 per cent., whilst the manganese may reach 15 per cent. Beyond this amount the carbon diminishes, and the bladed structure disappears, while the alloy becomes known as *ferro-manganese.*

The principal localities for the manufacture are in the Rhenish provinces of Prussia, where it is made from the spathic ores of Siegen, mixed with brown and red iron-ores of the same locality, and from foreign countries; low-class manganese-ores from Nassau being used to increase the proportion of manganese when deficient. Under favourable circumstances from $\frac{1}{4}$ to $\frac{1}{2}$ of the manganese in the charge passes into the slag; whilst from $\frac{3}{4}$ to $\frac{1}{2}$ is reduced. In this country the ore used is principally the manganesiferous brown ores of Carthagena, or mixtures of iron-ores with others containing manganese. The average of the best Rhenish spiegeleisen contains about 10 per cent. of manganese. It was formerly used for re-carburizing the overblown metal in the Bessemer converter, but now an alloy richer in manganese is generally preferred. The lower quality of spiegeleisen is used for conversion into wrought iron in the puddling furnace.

Spiegeleisen is made in America from Franklinite, and in Sweden from Knebelite.

As the conditions of working are similar to those in producing grey iron all the phosphorus contained in the ore will be reduced; it is therefore necessary to be as careful in selecting the materials for spiegeleisen as in making Bessemer pig-iron.

The iron made from ores with a smaller proportion of manganese than can be used for making spiegeleisen is known as *spiegelig* or *weiss-strahlig*, which has either small facetted, or a columnar, fracture. A pig-iron of this class, containing about 2 per cent. of manganese, is made at Weardale, in Durham, from the spathic ores in the lead mines of that district. See Steel.

SPINDLE-TREE OIL. See Oils.

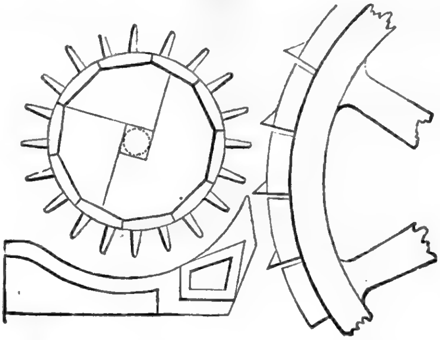
SPINEL or **SPINELLE.** See Ruby.

SPINET, THE. A musical instrument which was much admired by our grandmothers. It had some resemblance in shape to a modern semi-grand piano, but was much smaller, and, though sufficiently pleasing, very much less effective in tone. It was played similarly to the modern method, by means of keys putting in motion a mechanism to touch a single string, which emitted the sound on being struck. The instrument being small, and its mechanism slight and simple, its price was proportionately moderate, and the spinet was thus within the reach of those who could not afford the more pretentious and elaborate harpsichord.

The *Clavicord* was a similar instrument, but smaller; and instead of being struck by a jack, the strings were pressed by brass-pins projecting from the end of the keys. It was sometimes called a clarichord, and occasionally the manuchord. Under these names, the spinet is often confounded.

SPINNING. The greatest improvement hitherto made in forming textile fabrics, since the era of Arkwright, is due to Mr. G. Bodmer of Manchester. By his patent inventions, the several organs of a spinning-factory are united in one self-acting and self-supplying body—a system most truly *automatic*. His most comprehensive patent was obtained in 1824, and was prolonged by the Judicial Committee of the Privy Council, for 7 years after the period of 14 years was expired. It contained the first development of a plan by which fibres of cotton, flax, &c., were lapped and unlapped through all the operations of cleaning and blowing, carding, drawing, roving, and spinning; in the latter, however, only as far as the operation of feeding is concerned. The patent of 1824 was the beginning; the result of which was several other patents for improvements.

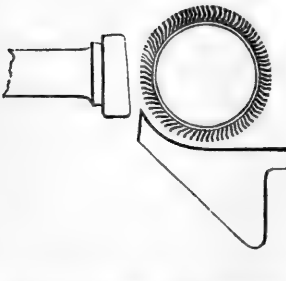
1866



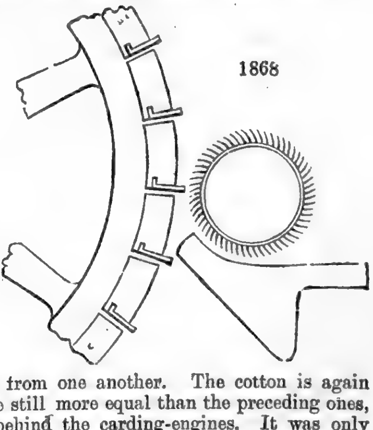
By a machine generally called a Devil or Opener ('*Wolf*,' in German), which consists of a feeding-plate set with teeth, and a roller covered with spikes (see *fig.* 1866), the cotton is cleared from its heaviest dirt and opened. This machine delivers the cotton into a room or on to a travelling-cloth, from which it is taken, weighed in certain portions, and spread upon cloth in equal portions; this is then rolled up, and placed behind the first blower.

The first blower has a feeding-plate like *fig.* 1867 without teeth, and over this plate the cotton is delivered to the operation of the common beaters, from which it is received into a narrow compartment of 4½ or 5 inches broad, and wound, by means of his lap-machines, upon rollers in beautifully level and well-cleaned lays. Eight of these narrow laps are then placed behind a second blower, of a similar construction to the first. Instead of the common beater, however, a drum with toothed straight edges is used (see *fig.* 1868), which opens the cotton still more, and separates the fibres from one another. The cotton is again formed into similar narrow laps, which are still more equal than the preceding ones, and eight of these laps are then placed behind the carding-engines. It was only by applying the lap-machine, that he succeeded in forming small laps on the blower; without this the doffing of the laps without stopping the wire-cloth could not be effected, and in doing this, an irregular lap would be formed, because of the accumulating of the falling cotton in one place while the wire-cloth was standing.

1867



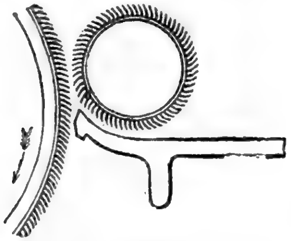
1868



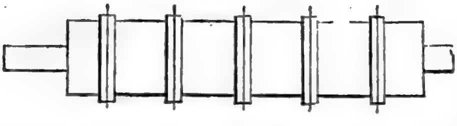
Carding Engine.—When a set of cards work together, any interruption or stoppage of a single carding-engine causes a defect in the produce of the whole lap. Interruptions occurred several times a day by the stripping of the main cylinder, and during this operation, the missing band or silver was supplied out of a can, being the produce of a single carding-engine working into cans (a spare card). The more objectionable defect was, however, the difference of the product of the carding-engine after the main cylinder had been stripped; the band or silver from it will be thin and light, until the cards of the main cylinder are again sufficiently filled with cotton, when the band will again assume its proper thickness. Another irregularity was caused by the stripping of the flats or top cards, but was not so fatal as the first one. These defects were, of course, a serious drawback to the system of working, the latter of which was provided against by stripping the top cards by mechanism; the former was conquered by the invention of the self-strippers for the main cylinders; thus the carding-engine may now work from Monday morning to Saturday night without interruption, the cylinders requiring only to be brushed out every evening; the consequence is, that much time is gained, and a very equal, clean, and clear product is obtained. Old carding-engines to which he applied his feeders (see *fig.* 1869) and main cylinder-clearers produce much superior work, and increase the production from 18 to 24 per cent.

The main cylinder-clearer consists of a very light cast-iron cylinder, upon which five, six, or more sets of wire-brushes are fixed, which are caused to travel to and fro across the main cylinder; the surface or periphery of the brushes overrunning the surface or periphery of the main cylinder by 8 or 19 per cent., the brushes thus lifting the cotton out of the teeth of the cards of the main cylinder, and causing the dirt and lumps to fall.

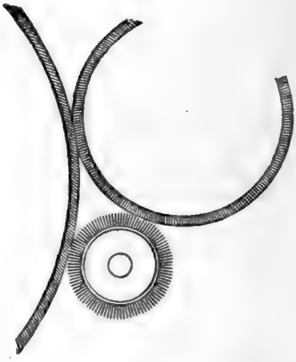
1869



1870



1871

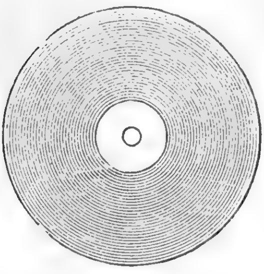


As the brushes are not above a quarter-inch in breadth and travel to and fro, it is clear that no irregularity can take place in the fleece which comes from the doffer; not more than 1-40th part of the breadth of the cylinder being acted upon at the same time. *Figs.* 1870, 1871, give an idea of the clearer: the mechanism within the clearer, and by which the brushes are caused to travel is simple and solid. The main cylinders for the carding-engines are made of cast iron, the two sets of arms and rims are cast in the same piece; when complete, they weigh 50 lbs. less than those made of wood.

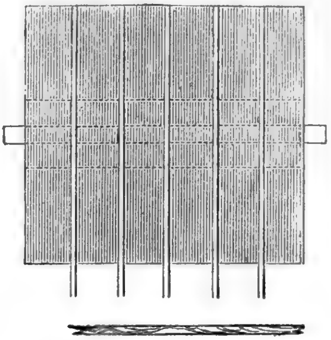
The lap machine connected with these engines is almost self-acting; a girl has only to turn a crank when the lap is full; by this turn the full lap is removed, and an empty roller put in its place, the band of cotton is cut, and no waste is made.

Drawing Frame.—The laps from the carding-engine lap-machine are put upon delivering rollers, behind a set of drawing rollers, and from them delivered upon a belt or trough, and again formed into laps similar to those from the carding-engines. The next operation formed the laps into untwisted rovings, and the next again into smaller untwisted rovings, or rovings with false twist in them. The false twist was objectionable, and a number of rovings on the same bobbin, with left and right permanent twist in them was adopted. This does very well; there is, however, a little objection to that place in which the twist changes from right to left when it comes to the last operation before spinning. The left and right hand twist is confined to the drawing-frame, which converts two laps into one roving, and forms a roller or bobbin of 14 inches diameter and 15 inches broad, with six separate and twisted rovings wound upon it. (See *figs.* 1872, and 1872*a.*) The twist is given by tubes in two directions, so that it remains in it (see *fig.* 1872*a*), the tube turns in the same direction, while the roving advances 4 or 5 inches, and then turns in the other direction. These laps or bobbins are then placed behind a machine, which he calls a coil-frame, the most important arrangement of which he claimed already in his patent of 1835. It consists of a slot, with a travelling spout, without which the coils cannot be formed under pressure.

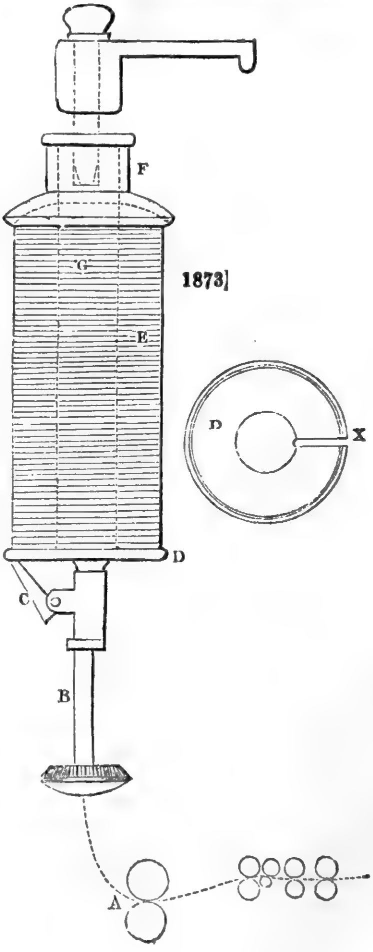
1872



18



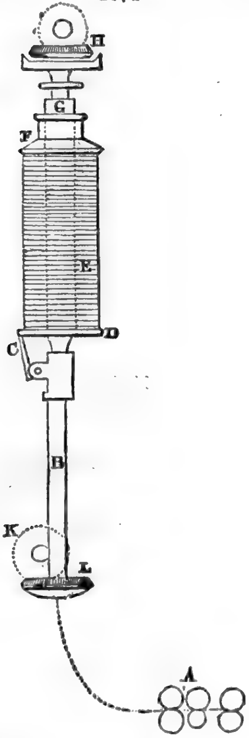
Coil Frame.—The bobbins (*fig.* 1872) are placed behind this machine, and two ends from the bobbin are passed through the drawing rollers, and formed into one untwisted silver or roving in the following manner:—When the cotton has passed through the drawing rollers and calender rollers, A, (see *fig.* 1873) it is passed through the tube, B, and the finger, C; the spindle with its disc, D, revolves in such a proportion as to take up the cotton which proceeds from the calendar rollers, A, and cause the rovings to be laid down in a spiral line closely, one by one; and as the rollers, A, work at a regular speed, it is evident that the motion of the finger, C, and the speed of the tube, B, must vary accordingly. The coil, E, is stationary, and is pressed by the lid or top, F, which slides up the spindle, G, made of tin-plate. The cotton enters through the slot, X, *fig.* 1873. It is quite evident that the finger, C, and spindle, G, only perform one and the same varying motion, which is repeated at every fresh layer, and the coil is thus built from below; it is about 8 inches in diameter and 18 inches high when compressed, and contains 4½ lbs. of cotton. There are several modes of forming these coils, but one only is shown here. These coils are placed behind the twist-coil frames in half-cans or partly open ones or troughs, or behind a winding machine, where they are wound upon rollers side by side, like the lap or bobbin shown in the drawing frame, and placed behind the twist-coil frame in this state.



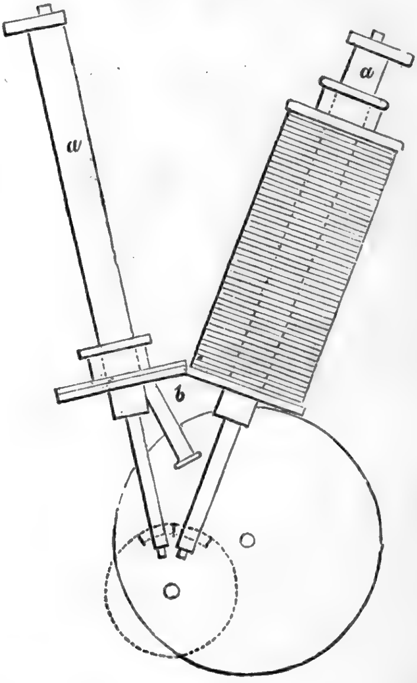
1873]

Twist-coil Frame.—This frame forms rovings into coils similar to those above explained, with this difference: that the rovings are fine, say, from 1 to 10 hanks per pound, and regularly twisted; their diameter varies from 2½ to 5 inches. The same machines produce rovings more or less fine, but the diameter of the coils does not differ. The difference of this machine from that above described consists in the dimensions of their parts, and in its having the spindle, G, and the lid or top, F, revolving, as well as the tube, B. (See *fig.* 1874.) In this machine the motion of the spindle, B, is uniform: the spindle, G, however, is connected by the bevel-wheels, H and I, with a differential motion at the end of the frame, with which the motion of the finger, C, corresponds. The skew-wheels, K and L, are connected with the drawing rollers, A. The speed of the tube, B, and the spindle, G, are so proportioned, that while the spindle, G, performs one revolution, and therefore puts one twist into the roving, the tube, B, also performs one revolution, missing so much as will be required to pass through the slot in the cap or disc, D, and lay on it as much of the roving as proceeds from the rollers, A, and in which one twist is contained. Of course the twist of these rovings can be adapted to their fineness and varied; but it is evident that, on account of the regularity of the machine and its simplicity of movement, the rovings can never be stretched, and much less twist can be put into them than can be put in the common fly-frames. These coils are put behind the spinning machines on shelves or in small cans, open in front; or they are wound from 24 to 72 ends upon bobbins, and placed upon unlap rollers behind the spinning frames.

1874



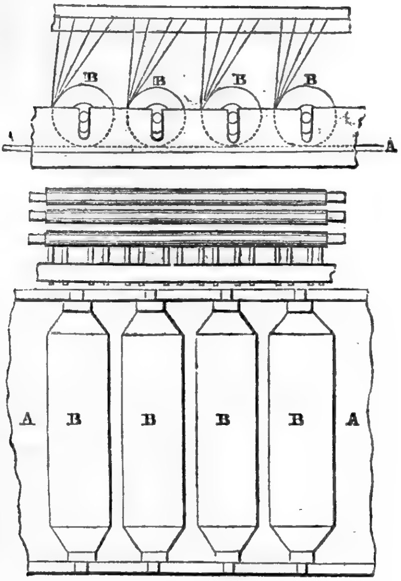
1875



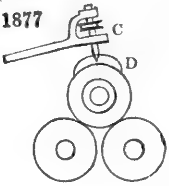
Coiling Machine for Carding Engines and Drawing Frames.—These are simple machines, which may be applied to carding engines or drawing frames of any description. They form large coils, 9 inches in diameter and 22 inches long, when on the machine. There are two spindles (see *a*, *fig.* 1875) on each machine, for the purpose of doffing without stopping the drawing frame and carding engines. When one coil is filled, the finger, *b*, is just brought over to the other spindle, so that the full coil is stopped and the new one begins to be formed without the slightest interruption of the machine.

Coils are formed in various ways, also in cans; but this description is sufficient to show the application of this mode of winding up bands or rovings. Several of the above-described machines are adapted with equal success to wool and flax. Winding directly from the carding engines the slivers separately upon long bobbins, twist is given in two directions, for the purpose of uniting the fibres to some extent, so that they may not only come off the bobbins without sticking to one another, but also that they may draw smoother. Another machine is used by which several rovings, say 4 or more, are put upon the same bobbin with conical ends; these bobbins are placed behind the mules or throstles, and are unwound by a belt or strap running parallel with the fluted rollers of the spinning machine, as seen in *fig.* 1876. The belt or band, A, is worked in a similar way to that described in a former patent, and the bobbins, B, rest upon and revolve upon their surface, exactly according to the speed of the belt. The most important feature in the roving machine is a metal plate, in which a slot is formed through which the rovings pass; this slot is seen in *figs.* 1877, 1878, and 1879.

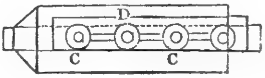
1876

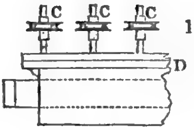


1877

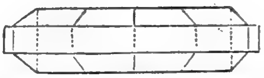


1878





1879

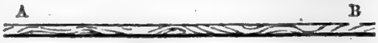


The cotton, when coming from the drawing rollers, is passed through the twisters, C, and through the slot in the plate, D. Any convenient number of neatly-formed and perfectly separate coils can be put upon the wooden barrel or bobbin. The bobbin formed upon these machines is represented in *fig.* 1880, and the conical ends are formed by a mechanism, by which the twisters, C, are caused to approach a little more to one another, after each layer of rovings has been coiled round the barrel: the section of the bobbin is, therefore, like that shown in *fig.* 1880.

Rovings wound upon bobbins by means of tubes revolving in one direction are certainly not so fit for spinning as rovings into which a small degree of twist is put. The tube by which a twist is put in on one side and taken out at the other, curls or ruffles the cotton, and causes it to spread out as it passes between the rollers, while rovings with a little permanent twist in them are held together in the process of drawing, and thus produce smooth yarn. To remedy the evil above described, when untwisted rovings are used, the spouts or guides, through which the rovings pass into or between the drawing rollers, are made to revolve slowly, first in one, and then in the other direction, and thus a certain quantity of twist is put into the rovings while they are being prepared for spinning.

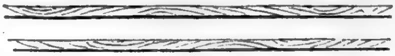
There is a little defect in the working of the rovings with reversed twist when too much or too little twist is put in them, or when the winding machine is not kept in good order. This defect proceeds from the change in the twist of the roving seen at A, *fig.* 1881; in this place the twist is not like that at B, and it would in some parts of the yarn, be detected under circumstances just described. In cases where double rovings are used, the twisters are so arranged as to put the twist in the rovings, as shown in *fig.* 1882; in this case the reversing place of one roving meets the twisted place of the other, and the fault is completely rectified.

1881

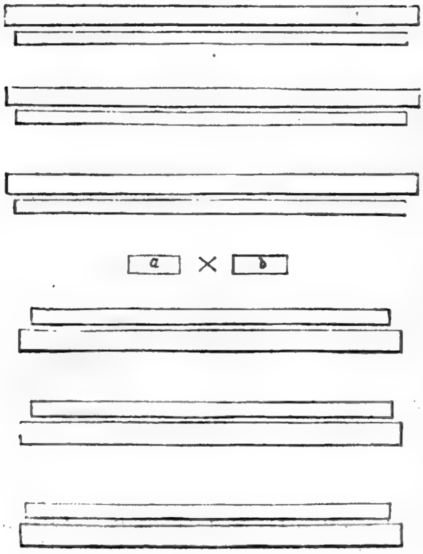


A self-actor, namely a machine in itself, which can be attached to 2, 3, or even 4 mules of almost any convenient number of spindles is sometimes employed. The mules are previously stripped of all their mechanism, except the rollers and their wheels, the carriage and spindles; all the other movements ordinarily combined with the mule are contained in the machine, which is placed between a set of mules, as seen in *fig.* 1883; *a* and *b*, the self-actors, to each of which 3 mules are yoked, and which are connected by bands and shafts with the self-actor, or rather partly self-actor. A girl of fifteen or sixteen years old stands at × between *a* and *b*, and never leaves her place except, perhaps, for aiding in doffing or in banding the spindles. The gearing of the room acts by means of straps upon the machines *a* and *b*, and from these machines all the movements are given to the six mules, namely, the motion of the rollers, the spindles, the drawing out of the carriage, the after draft, &c. When the carriages are to be put up, the girl takes hold of two levers of the machine *a*, and by moving them in certain proportions, acts upon two cones and pulleys, and thus causes, in the most easy and certain manner, the carriages to run in and the yarn to be wound on the spindles. The first machine made for this purpose was completely self-acting, but it was found that the mechanism was more complicated and apt to get out of order; and as it was necessary to have a girl of a certain age to watch over the piecers for a certain number of mules, the simplified machine above described was adopted; placing the girl near these machines, from whence the whole set of mules attached to the same can be overlooked; as the creels behind the mules are not wanted in this system, this impediment to the sight of the girl would be removed.

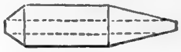
1882



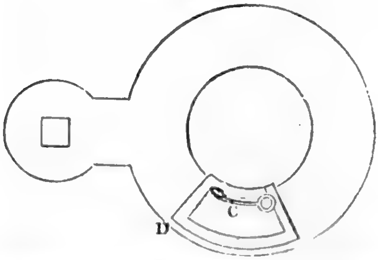
1883



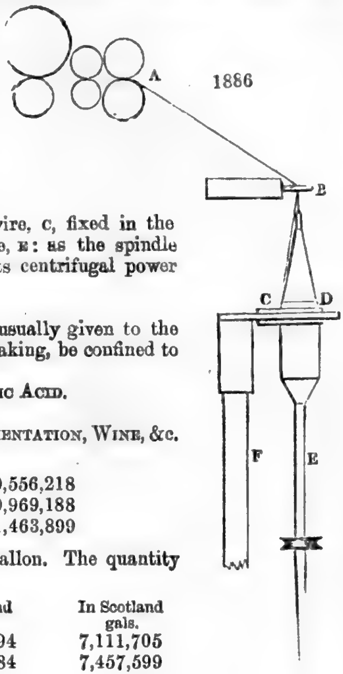
1884



1885



Bastard Frame.—The simple bastard frame is a throstle with mule spindles, forming cops, as seen in *fig.* 1884, and wound so hard that they can be handled about without any danger of spoiling them; in the same dimensions they contain one-third more yarn than the best cops of self-actors. The machine is extremely simple; but with them they are not able to spin advantageously upon large machines above No. 20's. The quantity this machinery produces is nearly one-third more than the best self-actor, on an equal number of spindles, and the yarn and cops are much superior. Of course there is a copping motion connected with the machine: the winding, however, is continuous, as well as the twisting, and *figs.* 1885 and 1886 will give the reader an idea of the frame. The yarn coming from the rollers, A, goes through an eye, B, to the wire, C, fixed in the flyer, D, and from thence on the mule spindle, E: as the spindle revolves, the flyer is dragged along, and by its centrifugal power winds the yarn tight upon the spindles.



1886

SPIRATOR. See ASPIRATOR.

SPIRIT OF AMMONIA. The name usually given to the solution of ammonia. It should, strictly speaking, be confined to the solution in spirit only. See AMMONIA.

SPIRIT OF SALT. See HYDROCHLORIC ACID.

SPIRITS OF WINE. See ALCOHOL.

SPIRITS, VINOUS. See ALCOHOL, FERMENTATION, WINE, &c. The *Revenue* produced by spirits in

1868–69	amounted to . .	£10,556,218
1869–70	,, . . .	10,969,188
1870–71	,, . . .	11,463,899

The *Rate of duty* in 1870–71 was 10*s.* the gallon. The quantity charged with duty was:—

Years	In England and Wales gals.	In Ireland gals.	In Scotland gals.
1868–69	9,056,094	5,762,594	7,111,705
1869–70	9,359,946	6,037,684	7,457,599
1870–71	9,637,339	6,448,413	7,757,696

The *Quantity distilled* during the year:—

	1868–69 gals.	1869–70 gals.	1870–71 gals.
England and Wales .	7,190,380	7,280,088	7,576,495
Scotland	12,197,087	13,799,071	14,501,983
Ireland	6,010,764	6,599,636	8,873,545
	25,398,231	27,678,795	30,952,023

The *Value* of British spirits shipped as merchandise, not including ships' stores:

Years	£	Years	£
1866	151,073	1870	183,291
1867	289,206	1871	200,570
1868	257,565	1872	236,186
1869	209,953	1873	210,964

Spirits *Imported* in 1874:—	Proof gals.	Value
Rum	8,188,456	£922,083
home consumption	5,194,793	...
Brandy	3,401,838	1,460,073
home consumption	4,308,816	...
Other sorts	2,192,965	229,872
home consumption	1,131,603	...

Spirits, British and Irish, *Exported* in 1874, 1,213,314 gallons; value £151,665.

SPLINT COAL. Sometimes *Splent.* A term, originating in Scotland, and applied to a hard and sometimes imperfectly-laminated variety of bituminous coal. The name appears to be derived from its splitting (Scot. *splenting*) up into flakes, or laminæ. The splint coals are a valuable variety, since they burn with great heat, and do not cake.

SPONGE. (*Éponge*, Fr.; *Schwamm*, Ger.) Although for a long time it was a disputed point whether the sponge of commerce belonged to the animal or the vegetable kingdom, its animal nature is now well proved, and sponges are regarded as a family of animals forming a class by themselves, *Porifera* or *Spongidæ.*

The sponge consists of a soft gelatinous mass, mostly supported by an internal skeleton composed of reticularly anastomosing horny fibres, in or among which are usually imbedded siliceous or calcareous spicula. Sponges are mostly marine; two or three species only being found in fresh water. In the living state they possess lively colours, and usually grow in groups, upon rock, shells, polypes, crustacea, and occasionally on sea-weeds. The horny fibres forming the skeletons of sponges are cylindrical and variously united, so as to form a network, often of great beauty. By dissolving the chalk from the sponge-formed fossil in that formation, many very delicate and regular systems of meshes may be obtained. Some beautiful siliceous sponge-skeletons have been brought to this country from the Japanese seas. The gelatinous substance covering the skeleton of sponges resembles the sarcode of which the *Amœbæ* are composed, and appears to consist of minute 'sponge particles,' those lining the internal chambers being furnished with cilia. During life, by means of these, water, entering by the small apertures, or pores, and reaching the channels, is expelled in intermittent currents through the large 'oscula.' Sponges are fixed by a kind of root, by which they hold firmly to any surface upon which they once fix themselves. Sponges may be propagated by division, but more usually by gemmules, which detach themselves from the parent body, and float about until they find a fitting resting-place, when they fix themselves and grow. Sponges adhere firmly to the rocks or other bodies upon which they grow, and are not to be detached without considerable trouble. The inhabitants of the Grecian Archipelago are trained from infancy to dive for these substances. Naturalists distinguish three kinds of sponges, each of which is composed of many species, and these form as many groups or divisions. The genus *Spongia*, which comprehends the sponges of commerce, is the type. The siliceous sponges, *Silicea*, have the body, or gelatinous portion, curiously strengthened with siliceous spicula. The calcareous sponges, *Calcarea*, have spicula of carbonate of lime supporting a sub-cartilaginous substance, which is not so soft as the coverings of the other sponges. The horny sponges, *Cornea*, have no spicula, the body is very porous and elastic, being composed of a fibro-corneous skeleton, the parts of which communicate with each other in all directions.

The sponges of commerce are obtained from the Mediterranean, Smyrna being the principal mart. Sponges are treated with muriatic (hydrochloric) acid to remove the lime; they are then dried, well beaten, and again soaked in water, which is frequently changed. Very inferior sponges are prepared for the English market by bleaching, either with hydrochloric acid or chlorine. By this means a very good colour is produced, but the sponge is rendered very rotten.

An interesting account of the sponge fishery of the Ottoman Archipelago, by M. Bilioti, the British Vice-Consul at Rhodes, appeared in the *Technologist*, from which the following particulars are abstracted:—'Sponges form the principal article of exportation from this district, and a great portion of them is sent to Great Britain. There are nearly as many different qualities of fine, common, and coarse sponges as there are spots of fishery. The sponges in this quarter are known in commerce by the names of the respective coasts where the inhabitants of the islands of the Ottoman Archipelago dive for sponges. These may be divided into five categories, besides the ordinary classification of fine, common, and coarse.'

Merchants when they purchase sponges take into consideration the form, size, and colour, the quantity of extraneous matter, such as stones and sand, which come out in proportion of their being washed more or less when fished. All this renders the trade very difficult, the more so as (with the exception of Mandruha and Bengazi, which are sold at so much a piece) the sponges are usually sold in a lump. Latterly the divers have offered their sponges for sale without sanding them (finding that it was no profit to do so), and the merchants again purchase them by weight.

A French *savant*, M. Artus, has been experimenting on the bleaching of sponges. Some good sponges were well washed in river-water. Whilst still wet, they were placed in a bath of six parts water and one part commercial hydrochloric acid, and were allowed to remain until all the carbonic acid gas was discharged. They were then washed again, and afterwards strung together and immersed in hydrochloric acid diluted with 6 per cent. of hyposulphite of soda dissolved in water. The vessel was then closed and left for 48 hours, when the sponges were taken out, washed and dried. M. Artus tried another experiment in which the quantity of hyposulphite of soda was doubled. In a third experiment the sponges were, on removal from the bath, treated with hydrochloric acid, subsequently washed, and then exposed to sulphurous acid gas. The sponges, however, by each of these processes were not thoroughly bleached, and a fourth method was tried. The sponges were well washed in hot diluted soda-lye, then placed in a bath of weak hydrochloric acid and hyposulphite of soda, using only half the quantity of hyposulphite that was used in the first experiment, and a very satisfactory result was thus obtained.

SPONTANEOUS COMBUSTION. Major Majendie has recently (1874) communicated to the Royal Artillery Institute some interesting experiments made by Mr. Galletly on this subject. It was found that cotton-waste, soaked in boiled linseed oil and wrung out, if exposed to a temperature of 170° Fahr., oxidised in 105 minutes. Raw linseed oil required from four to five hours before igniting; rape and olive oils five to six hours; lard oil four hours; castor oil one day; and, in one trial, olive oil ignited in 100 minutes. Sperm oil did not char the waste. His theory is, that the oil by being spread and finely divided among the fibres of the waste, has its absorbent power towards oxygen greatly increased, much as a bloom of iron will oxidise rapidly in process of manufacture if exposed to the air. It was also found that ignition took place more quickly with silk waste than with cotton. A scientific journal, commenting on this report, declares that the sperm oil of the experiment must have been adulterated with petroleum, which has a tendency to repress such oxidation, as it has been proved by other trials that sperm oil will rapidly absorb oxygen as certainly as other oils; but no case of spontaneous combustion has yet been reported from coal oils.

Many fires have occurred in woollen and cotton mills from the careless leaving of oily waste in warm places, especially during the summer months, and for safety it is necessary that such waste be removed daily. Shoddy mills, where the rags after being oiled are torn into fibre, are especially dangerous, as either from inferior oil used, or the adulteration of No. 1 lard oil with the dangerous cotton-seed oil, the shoddy often takes fire in the bags before leaving the works, or soon after reaching the mill where it is to be manufactured. Two other causes may aid in causing such fires: packing the material too soon and too tight, and putting on too much oil. The latter is a profitable arrangement, and too much practised. The only safety for those buying is to examine the heat of each lot as received, and, if possible, open out into a pile; or, if not, let each bag be slit open and exposed to the air. The Editor of this Dictionary was called upon to investigate the causes which led to the destruction by fire of H.M. ships the 'Imogene' and the 'Talavera' in Devonport dockyard. He traced it, beyond all question, to a large bin, in which, with great carelessness, oil, anti-attrition, oakum, and tow, which had been used by the shipwrights and others in wiping the oil from their tools after sharpening them, had been allowed to accumulate; and reported to this effect to the Admiralty.

Spontaneous combustion, arising from the rapid absorption of oxygen by the fixed oils, except petroleum, is now attracting much attention, and cannot be too much impressed on the public mind. The recent fire at Portland, Maine, is declared to have arisen from the leakage of linseed oil, stored alongside of rags. In May last two fires, discovered first in the stable, and afterwards in the dwelling of a gentleman at Bedford, Pa., were traced directly to rags saturated with linseed oil, which painters who had been graining shutters had thrown into corners. At Jamestown, New York, a workman, who had been cleaning furniture with linseed oil, threw aside his oily apron crumpled together, and in a short time it was found in a state of ignition.

SPOON MANUFACTURE. See STAMPING OF METALS.

SPRUCE BEER is prepared as follows:—Essence of spruce, half a pint; pimento and ginger bruised, of each 4 ounces; hops, from 4 to 3 ounces; water, 3 gallons. Boil for ten minutes, then strain and add 11 gallons of warm water, a pint of yeast, and 6 pints of molasses. Mix and allow the mixture to ferment for twenty hours.

SPRUCE, ESSENCE OF, is prepared by boiling the young tops of the *Abies nigra*, or black spruce, in water, and concentrating the decoction by evaporation.

STAINED GLASS. Under GLASS, a general account of the processes for colouring glass has been given; for the manufacture, however, of stained glass for windows some special details have been reserved for this place. When certain metallic oxides or chlorides, ground up with proper fluxes, are painted upon glass, their colours fuse into its surface at a moderate heat and make durable pictures, which are frequently employed in ornamenting the windows of churches, as well as of other public and private buildings. The colours of stained glass are all transparent, and are therefore to be viewed only by transmitted light. Many metallic pigments, which afford a fine effect when applied cold on canvas or paper, are so changed by vitreous fusion as to be quite inapplicable to painting in stained glass.

The glass proper for receiving these vitrifying pigments should be colourless, uniform, and difficult of fusion; for which reason crown glass, made with little alkali, or with kelp, is preferred. When the design is too large to be contained on a single pane, several are fitted together and fixed in a bed of soft cement while painting, and then taken asunder to be separately subjected to the fire. In arranging the glass pieces, care must be taken to distribute the joinings, so that the lead frame-work may interfere as little as possible with the effect.

A design must be drawn upon paper, and placed beneath the plate of glass; though the artist cannot regulate his tints directly by his pallet, but by specimens of the colours producible from his pallet pigments after they are fired. The upper side of the glass being sponged over with gum-water, affords, when dry, a surface proper for receiving the colours, without the risk of their running irregularly, as they would be apt to do, on the slippery glass. The artist first draws on the plate with a fine pencil all the traces which mark the great outlines and shades of the figures. This is usually done in black, or at least, some strong colour, such as brown, blue, green, or red. In laying on these the painter is guided by the same principles as the engraver, when he produces the effect of light and shade by dots, lines, or hatches; and he employs that colour to produce the shades, which will harmonise best with the colour which is to be afterwards applied; but for the deeper shades, black is in general used. When this is finished, the whole picture will be represented in lines or hatches similar to an engraving finished up to the highest effect possible; and afterwards, when it is dry, the vitrifying colours are laid on by means of larger hair-pencils; their selection being regulated by the burnt specimen tints. When he finds it necessary to lay two colours adjoining, which are apt to run together in the kiln, he must apply one of them to the back of the glass. But the few principal colours to be presently mentioned, are all fast colours which do not run, except the yellow, which must therefore be laid on the opposite side. After colouring, the artist proceeds to bring out the lighter effects by taking off the colour in the proper place, with a goose-quill cut like a pen without a slit. By working this upon the glass, he removes the colour from the parts where the lights should be the strongest; such as the hair, eyes, the reflection of bright surfaces, and light parts of draperies. The blank pen may be employed either to make the lights by lines, or hatches and dots, as is most suitable to the subject.

By the metallic preparations now laid upon it, the glass is made ready for being fired, in order to fix and bring out the proper colours. The furnace or kiln best adapted for this purpose, is similar to that used by enamellers. (See ENAMEL, and the *Glaze-kiln*, under POTTERY.) It consists of a muffle or arch of fire-clay or pottery, so set over a fire-place, and so surrounded by flues, as to receive a very considerable heat within, in the most equable and regular manner: otherwise, some parts of the glass will be melted; while, on others, the superficial film of colours will remain unvitrified. The mouth of the muffle, and the entry for introducing fuel to the fire, should be on opposite sides, to prevent as much as possible the admission of dust into the muffle, whose mouth should be closed with double-folding doors of iron, furnished with small peep-holes, to allow the artist to watch the progress of the staining, and to withdraw small trial slips of glass, painted with the principal tints used in the picture.

The muffle must be made of very refractory fire-clay, flat at its bottom, and only 5 or 6 inches high, with such an arched top as may make the roof strong, and so close on all sides as to exclude entirely the smoke and flame. On the bottom of the muffle a smooth bed of sifted lime, freed from water, about half an inch thick, must be prepared for receiving the pane of glass. Sometimes several plates of glass are laid over each other with a layer of dry pulverulent lime between each. The fire is now lighted, and most gradually raised, lest the glass should be broken; and after it has attained to its full heat, it must be kept for three or four hours, more or less, according to the indications of the trial slips; the yellow colour being principally watched, as it is found to be the best criterion of the state of the others. When the colours are properly burnt in, the fire is suffered to die away slowly, so as to anneal the glass.

STAINED GLASS-PIGMENTS. *Flesh colour.*—Take an ounce of red lead, two ounces of red enamel (Venetian glass enamel, from alum and copperas calcined together), grind them to fine powder, and work this up with spirits (alcohol) upon a hard stone. When slightly baked, this produces a fine flesh colour.

Black colour.—Take 14½ ounces of smithy scales of iron, mix them with two ounces of white glass (crystal), an ounce of antimony, and half an ounce of manganese; pound and grind these ingredients together with strong vinegar. A brilliant black may also be obtained by a mixture of cobalt blue with the oxides of manganese and iron. Another black is made from three parts of crystal glass, two parts of oxide of copper, and one of (glass of) antimony worked up together, as above.

Brown colour.—An ounce of white glass or enamel, half an ounce of good manganese; ground together.

Red, Rose, and *Brown colours* are made from peroxide of iron, prepared by nitric acid. The flux consists of borax, sand, and minium in small quantity.

Red colour may be likewise obtained from one ounce of red chalk pounded, mixed with two ounces of white hard enamel, and a little peroxide of copper.

A *red* may also be composed of rust of iron, glass of antimony, yellow glass of lead, such as is used by potters (or litharge), each in little quantity; to which a little sulphuret of silver is added. This composition well ground, produces a very fine red colour on glass. When protoxide of copper is used to stain glass, it assumes a bright red or green colour, according as the glass is more or less heated in the furnace, the former corresponding to the suboxide, the latter having the copper in the state of protoxide.

Bistres and *Brown reds* may be obtained by mixtures of manganese, orange oxide of copper, and the oxide of iron called umber, in different proportions. They must be previously fused with vitreous solvents.

Green colour.—Two ounces of brass calcined into an oxide, two ounces of minium, and eight ounces of white sand; reduce them to a fine powder, which is to be enclosed in a well-luted crucible, and heated strongly in an air-furnace for an hour. When the mixture is cold, grind it in a brass mortar. Green may, however, be advantageously produced by a yellow on one side, and a blue on the other. Oxide of chrome has been also employed to stain glass green.

A *fine Yellow colour.*—Take fine silver laminated thin, dissolve in nitric acid, dilute with abundance of water, and precipitate with solution of sea-salt. Mix this chloride of silver, in a dry powder, with three times its weight of pipe-clay well burnt and pounded. The back of the glass-pane is to be painted with this powder, for when painted on the face, it is apt to run into the other colours.

Another *yellow* can be made by mixing sulphide of silver with glass of antimony, and yellow ochre previously calcined to a red-brown tint. Work all these powders together, and paint on the back of the glass. Or silver laminæ melted with sulphur and glass of antimony, thrown into cold water, and afterwards ground to powder, afford a yellow.

A *pale yellow* may be made with the powder resulting from brass, sulphur, and glass of antimony, calcined together in a crucible till they cease to smoke; and then mixed with a little burnt yellow ochre.

The *fine yellow* of M. Merand, is prepared from chloride of silver, oxide of zinc, white-clay, and rust of iron. This mixture, simply ground, is applied on the glass.

Orange colour.—Take 1 part of silver powder, as precipitated from the nitrate of that metal by plates of copper, and washed; mix it with 1 part of red ochre and 1 of yellow, by careful trituration; grind into a thin pap with oil of turpentine or lavender, and apply this with a brush, dry, and burn in.

In the *Philosophical Magazine,* of December 1836, the anonymous author of an ingenious essay, 'On the Art of Glass-painting,' says, that if a large proportion of ochre has been employed with the silver, the stain is yellow; if a small proportion, it is orange-coloured; and by repeated exposure to the fire, without any additional colouring-matter, the orange may be converted into red; but this conversion requires a nice management of the heat. Artists often make use of panes coloured throughout their substance in the glass-house pots, because the perfect transparency of such glass gives a brilliancy of effect, which enamel painting, always more or less opaque, cannot rival. It was to a glass of this kind that the old glass-painters owed their splendid red. This is, in fact, the only point in which the modern and ancient processes differ; and this is the only part of the art which was ever really lost. Instead of blowing plates of solid red, the old glass-makers (like those of Bohemia for some time back), used to *flash* a thin layer of brilliant red over a substratum of colourless glass; by gathering a lump of the latter upon the end of their iron rod in one pot, covering with a layer of the former in another pot, then blowing out the two together into a globe or cylinder, to be opened into circular tables, or into rectangular plates. The elegant art of tinging glass red by oxide of copper, and flashing it on common crown glass, has become general within these few years.

That gold melted with flint-glass stains it purple was originally discovered and practised as a profitable secret by Kunckel. Gold has been recently used at Birmingham for giving a beautiful rose-colour to scent-bottles. The proportion of gold should be very small, and the heat very great, to produce a good effect. The glass must contain either the oxide of lead, bismuth, zinc, or antimony; for crown glass will take no colour from gold. Glass combined with this metal, when removed from the crucible, is generally of a pale rose colour: nay, sometimes is as colourless as water, and does not assume its ruby colour till it has been exposed to a low red heat, either under a muffle, or at the lamp. This operation must be nicely regulated; because a slight excess of fire destroys the colour, leaving the glass of a dingy brown, but with a green transparency like that of gold-leaf. It is metallic gold which gives the colour; and, indeed, the oxide is too easily reduced, not to be converted into the metal by the intense heat which is necessarily required.

Coloured transparent glass is applied as enamel in silver and gold *bijouterie* previously *bright-cut* in the metal with the graver or rose-engine. The cuts, reflecting the rays of light from their numerous surfaces, exhibit through the glass, richly stained with gold, silver, copper, cobalt, &c., a gorgeous play of prismatic colours, varied with every change of aspect. When the enamel is to be painted on, it should be made opalescent by oxide of arsenic, in order to produce the most agreeable effect.

The blues of vitrified colours are all obtained from the oxide of cobalt. Cobalt ore (sulphide) being well roasted at a dull red heat, to dissipate all the sulphur and arsenic, is dissolved in somewhat dilute nitric acid, and after the addition of much water to the saturated solution, the oxide is precipitated by carbonate of soda, then washed upon a filter and dried. The powder is to be mixed with thrice its weight of saltpetre; the mixture is to be deflagrated in a crucible, by applying a red hot cinder to it, then exposed to the heat of ignition, washed and dried. Three parts of this oxide are to be mixed with a flux, consisting of white sand, borax, nitre, and a little chalk, subjected to fusion for an hour, and then ground down into an enamel-powder for use. Blues of any shade or intensity may be obtained from the above, by mixing it with more or less flux.

The beautiful greenish-yellow, of which colour so many ornamental glass vessels have been lately imported from Germany, is made in Bohemia by the following process: An ore of uranium, as *Uran-ochre*, or *Uran-glimmer*, in fine powder, being roasted and dissolved in nitric acid, the filtered solution is to be freed from any lead present in it by the cautious addition of dilute sulphuric acid. The clear green solution is to be evaporated to dryness, and the mass ignited till it becomes yellow. One part of this oxide is to be mixed with three or more parts of a flux, consisting of 4 parts of red lead and 1 of ground flint; the whole fused together and then reduced to powder.

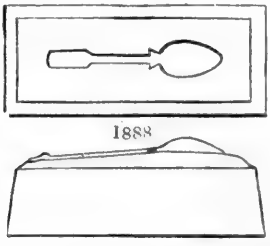
Chrome-green.—Triturate together in a mortar equal parts of chromate of potash and flowers of sulphur; put the mixture into a crucible and fuse. Pour out the fluid mass; when cool, grind and wash well with water, to remove the sulphuret of potash and to leave the beautiful green oxide of chrome. This is to be collected upon a filter, dried, rubbed down along with thrice its weight of a flux, consisting of 4 parts of red lead and 1 part of ground flints fused into a transparent glass; the whole is now to be melted and afterwards reduced to a fine powder.

Violet.—One part of calcined black oxide of manganese, 1 of zaffre, 10 parts of the white glass pounded, and one of red lead, mixed, fused, and ground. Or gold purple (Cassius's purple precipitate), with chloride of silver, previously fused with ten times its weight of a flux, consisting of ground quartz, borax, and red lead, all melted together. Or solution of tin being dropped into a large quantity of water, solution of nitrate of silver may be first added, and then solution of gold in *aqua regia*, in proper proportions. The precipitate is to be mixed with flux and fused.

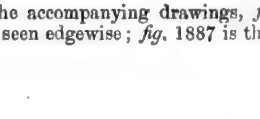
STAMPING OF METALS. The peculiar feature of improvement in the manufacture of stamped articles consists in producing the spoon, ladle, or fork perfect at one blow in the stamping machine, and requiring no further manipulation of shaping, but simply trimming off the barb or fin, and polishing the surface to render the article perfect and finished.

Formerly, in employing a stamping machine, or fly-press, for manufacturing spoons, ladles, and forks, it was the practice to give the impression to the handles, and to the bowls or prongs, by distinct operations of different dies, and after having so partially produced the pattern upon the article, the handles had to be bent and formed by the operations of filing and hammering.

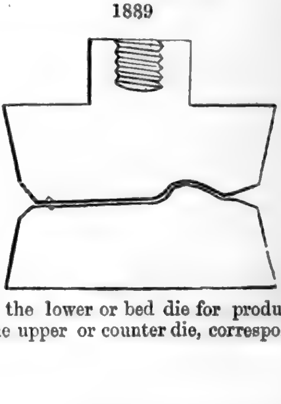
By Mr. Haynes' improved dies, which, having curved surfaces and bevelled edges, allow of no parts of the faces of the die and counter-die to come in contact, he is enabled to produce considerable elevations of pattern and form, and to bring up the article perfect at one blow, with only a slight barb, or fin, upon its edge.



1887



1888



1889

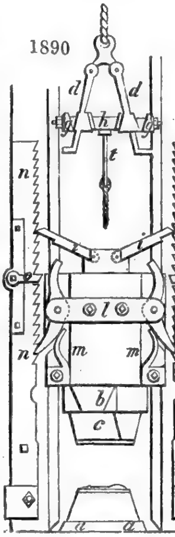
In the accompanying drawings, *fig.* 1888 is the lower or bed die for producing a spoon, seen edgewise; *fig.* 1887 is the face of the upper or counter die, corresponding;

fig. 1889 is a section, taken through the middle of the pair of dies, showing the space in which the metal is pressed to form the spoon.

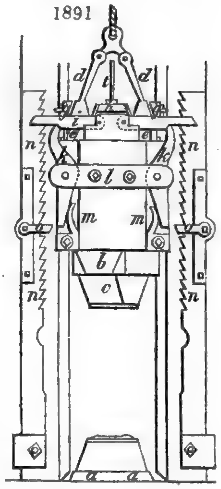
To manufacture spoons, ladles, or forks, according to his improved process, Mr. Haynes first forges out the ingot into flat pieces, of the shape and dimensions of the die of the intended article; and if a spoon or ladle is to be made, gives a slight degree of concavity to the bowl part; but, if necessary, bends the back, in order that it may lie more steadily and bend more accurately, upon the lower die; if a fork, he cuts or otherwise removes portions of the metal at those parts which will intervene between the prongs; and, having thus produced the rude embryo of the intended article, scrapes its entire surface clean and free from oxidation, scale, or fire-strain, when it is ready to be introduced into the stamping machine.

He now fixes the lower die in the bed of the stamping machine, shown at *a*, *a*, in the elevations *figs.* 1890 and 1891, and fixes, in the hammer *b*, the upper or counter die, *c*, accurately adjusting them both, so that they may correspond exactly when brought together. He then places the rudely-formed article above described upon the lower die, and having drawn up the hammer to a sufficient elevation, by a windlass and rope, or other ordinary means, lets go the trigger, and allows the hammer, with the counter die to fall upon the under die, on which the article is placed; when, by the blow thus given to the metal, the true and perfect figure and pattern of the spoon, ladle, or fork is produced, and which, as before said, will only require the removal of the slight edging of barb, or fin, with polishing, to finish it.

1890



1891



On striking the blow, in the operation of stamping the article, the hammer will recoil and fly up some distance, and if allowed to fall again with reiterated blows, would injure both the article and the dies; therefore, to avoid this inconvenience, he causes the hammer on recoiling to be caught by a pair of palls locked into racks on the face of the standards, seen in the figures; the hammer *b*, of the stamping machine, is seen raised and suspended by a rope attached to a pair of jointed hooks or holders, *d*, *d*, the lower ends of which pass into eyes *e*, *e*, extending from the top of the hammer. When the lever or trigger *t*, is drawn forward, as in *fig.* 1890, the two inclined planes, *g*, *g*, on the axle, *h*, press the two legs of the holders, *d*, *d*, inward, and cause their hooks or lower ends to be withdrawn from the eyes, *e*, *e*, when the hammer instantly falls, and brings the dies together: such is the ordinary construction of the stamping machine.

On the hammer falling from a considerable elevation, the violence of the blow causes it to recoil and bound upwards as before mentioned; it therefore becomes necessary to catch the hammer when it has rebounded, in order to prevent the dies coming again together; this is done by the following mechanism:—

Two latch-levers, *i*, *i*, are connected by joints to the upper part of the hammer, and two pall-levers, *k*, *k*, turning upon pins, are mounted in the bridge, *l*, affixed to the hammer. Two springs, *m*, *m*, act against the lower arms of these levers, and press them outwards, for the purpose of throwing the palls at the lower ends of the levers into the teeth of the ratchet racks, *n*, *n*, fixed on the sides of the upright standards.

Previously to raising the hammer, the upper ends of the pall-levers, *k*, are drawn back, and the latches, *i*, being brought down upon them, as in *fig.* 1890, the levers, *k*, are confined, and their palls prevented from striking into the slide racks; but as the hammer falls, the ends of the latches, *i*, strike upon the fingers, *o*, *o*, fixing to the side standards, and liberate the palls, the lower ends of which, when the hammer rebounds, after stamping, catch into the teeth of the racks, as in *fig.* 1891, and thereby prevent the hammer from again descending.

STAMPS. See Dressing of Ores.

STANNATE AND STANNITE OF POTASH AND SODA. Stannates and stannites of alkalis are valuable mordants. For the stannate of soda, 22 lbs. of caustic soda are first put into an iron crucible, heated to a low red heat, till the hydrate be produced; to which 8 lbs. of nitrate of soda and 4 lbs. of common salt are introduced. When the mixture is at a fluxing heat, 10 lbs. of feathered block-tin are added, and it is stirred with an iron rod. The mass now becomes dark coloured and pasty, and ammonia is given off (the tin decomposing the water of the hydrated soda and part of the nitrate of soda). The stirring is continued, as well as the heat, till deflagration takes place, and the mass becomes red hot and pasty. This product is stannate of soda. It may be purified by solution and crystallisation.

Stannite of soda is made by putting 4 lbs. of common salt, 13½ lbs. of caustic soda, and 4 lbs. of feathered block-tin into a hot iron crucible over a fire, and stirring and boiling to dryness, and as long as ammonia is given off. What remains is stannite of soda.

To produce the tin-preparing liquour, 3 lbs. of stannate of soda are dissolved in 1 gallon of boiling water, and 3 gallons or more of cold water, to bring it to the required strength. The stannite of soda is treated in the same way.

The process of Mr. James Young is much more recent, and presents a very beautiful application of science. Instead of reducing metallic tin from the ore, and oxidating the metal again to form the stannic acid at the expense of nitric acid, Mr. Young takes the native peroxide of tin itself, and fuses it with soda. The iron and other foreign metals present in the ore are insoluble in the alkali, so that by solution of the fused mass in water, a pure stannate of soda is obtained at once. It is crystallised by evaporation, and obtained in efflorescent crystals containing nine equivalents of water.

STARCH (*Amidon, Fécule,* Fr.; *Stärke,* Ger.) is a white pulverulent substance, composed of microscopic spheroïds, which are bags containing the amylaceous matter. It exists in a great many different plants, and varies in the form and size of its microscopic particles. As found in some plants, it consists of spherical particles $\frac{1}{1000}$th of an inch in diameter; and in others of ovoïd particles, $\frac{1}{300}$th or $\frac{1}{400}$th of an inch. It occurs: 1. In the seeds of all the acotyledonous plants, among which are the several species of corn, and those of other *Gramineæ.* 2. In the round perennial tap roots, which shoot up an annual stem; in the tuberose roots, such as potatoes, the *Convolvulus batatas* and *C. edulis,* the *Helianthus tuberosus,* the *Jatropha manihot,* &c., which contain a great quantity of it. 3. In the stems of several monocotyledonous plants, especially of the palm tribe, whence sago comes; but it is very rarely found in the stems and branches of the dicotyledonous plants. 4. It occurs in many species of lichen. Three kinds of starch have been distinguished by chemists; that of wheat, that called *inuline,* and lichen-starch. These three agree in being insoluble in cold water, alcohol, ether, and oils, and in being converted into sugar by either dilute sulphuric acid or diastase. The main difference between them consists in their habitudes with water and iodine. The first forms with hot water a mucilaginous solution, which constitutes, when cold, the paste of the laundress, and is tinged blue by iodine; the second forms a granular precipitate, when its solution in boiling-hot water is suffered to cool, which is tinged yellow by iodine; the third affords, by cooling the concentrated solution, a gelatinous mass, with a clear liquid floating over it, that contains little starch. Its jelly becomes brown-grey with iodine.

Ordinary Starch.—This may be extracted from the following grains:—Wheat, rye, barley, oats, buckwheat, rice, maize, millet, spelt; from the siliquose seeds, as peas, beans, lentiles, &c.; from tuberous and tap roots, as those of the potato, the orchis, manioc, arrow-root, batata, &c. Different kinds of corn yield very variable quantities of starch. Wheat differs in this respect, according to the varieties of the plant, as well as the soil, manure, season, and climate. See Bread.

Wheat partly damaged by long keeping in granaries may be employed for the manufacture of starch, as this constituent suffers less injury than the gluten; and it may be used either in the ground or unground state.

With unground wheat.—The wheat being sifted clean, is to be put into cisterns, covered with soft water, and left to steep till it becomes swollen and so soft as to be easily crushed between the fingers. It is now to be taken out, and immersed in clear water of a temperature equal to that of malting-barley, whence it is to be transferred into bags, which are placed in a wooden chest containing some water, and exposed to strong pressure. The water rendered milky by the starch being drawn off by a tap, fresh water is poured in, and the pressure is repeated. Instead of putting the swollen grain into bags, some prefer to grind it under vertical edge-stones, or between a pair of horizontal rollers, and then to lay it in a cistern, and separate the starchy liquor by elutriation with successive quantities of water well stirred up with it. The residuary matter in the sacks or cisterns contains much vegetable albumen and gluten, along with the husks; when exposed to fermentation, this affords a small quantity of starch of rather inferior quality.

The above milky liquor, obtained by expression or elutriation, is run into large cisterns, where it deposits its starch in layers successively less and less dense; the uppermost containing a considerable proportion of gluten. The supernatant liquor being drawn off, and fresh water poured on it, the whole must be well stirred up, allowed again to settle, and the surface-liquor withdrawn. This washing should be repeated as long as the water takes any perceptible colour. At the first turbid liquor contains a mixture of gluten, sugar, gum, albumen, &c., it ferments readily, and produces a certain portion of vinegar, which helps to dissolve out the rest of the mingled gluten, and thus to bleach the starch. It is, in fact, by the action of this fermented or soured water, and repeated washing, that it is purified. After the last deposition and decantation, there appears on the surface of the starch a thin layer of a slimy mixture of gluten and albumen, which being scraped off, serves for feeding pigs or oxen; underneath will be found a starch of good quality. The layers of different sorts are then taken up with a wooden shovel, transferred into separate cisterns, where they are agitated with water, and passing through fine sieves. After this pap is once more well settled, the clear water is drawn off, the starchy mass is taken out, and laid on linen cloths in wicker baskets, to drain and become partially dry. When sufficiently firm, it is cut into pieces which are spread upon other cloths, and thoroughly desiccated in a proper drying-room, which in winter is heated by stoves. The upper surface of the starch is generally scraped to remove any dusty matter, and the resulting powder is sold in that state. Wheat yields, upon an average, only from 35 to 40 per cent. of good starch. It should afford more by skilful management.

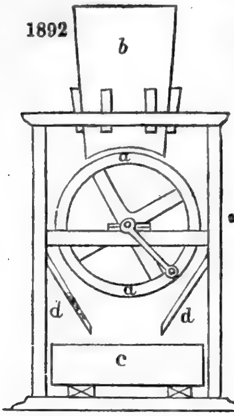
With crushed wheat.—In this country, wheat crushed between iron rollers is laid to steep in as much water as will wet it thoroughly; in four or five days the mixture ferments, soon afterwards settles and is ready to be washed out with a quantity of water into the proper fermenting vats. The common time allowed for the steep is from 14 to 20 days. The next process consists in removing the stuff from the vats into a stout round basket set across a back below a pump. One or two men keep going round the basket, stirring up the stuff with strong wooden shovels, while another keeps pumping water, till all the *farina* is completely washed from the bran. Whenever the subjacent back is filled, the liquor is taken out and strained through hair-sieves into square frames or cisterns, where it is allowed to settle for 24 hours; after which the water is run off from the deposited starch by plug-traps at different levels in the side. The thin stuff, called *slimes*, upon the surface of the starch, is removed by a tray of a peculiar form. Fresh water is now introduced, and the whole being well mixed by proper agitation, is then poured upon fine silk sieves. What passes through is allowed to settle for 24 hours; the liquor being withdrawn, and then the slimes, as before, more water is again poured in, with agitation, when the mixture is again thrown upon the silk sieve. The milky liquor is now suffered to rest for several days,—4 or 5,—till the starch becomes settled pretty firmly at the bottom of the square cistern. If the starch is to have the blue tint, called Poland, fine smalt must be mixed in the liquor of the last sieve, in the proportion of 2 or 3 lbs. to the cwt. A considerable portion of these slimes may, by good management, be worked up into starch by elutriation and straining.

The starch is now fit for *boxing*, by shovelling the cleaned deposit into wooden chests, about 4 feet long, 12 inches broad, and 6 inches deep, perforated throughout and lined with thin canvas. When it is drained and dried into a compact mass, it is turned out by inverting the chest upon a clean table, where it is broken into pieces 4 or 5 inches square, by laying a ruler underneath the sake, and giving its surface a cut with a knife, after which the slightest pressure with the hand will make the fracture. These pieces are set upon half-burned bricks, which by their porous capillarity imbibe the moisture of the starch, so that its under surface may not become hard and horny. When sufficiently dried upon the bricks, it is put into a stove (which resembles that of a sugar-refinery), and left there till tolerably dry. It is now removed to a table, when all the sides are carefully scraped with a knife; it is next packed up in the papers in which it is sold; these packages are returned into the stove, and subjected to a gentle heat during some days; a point which requires to be skilfully regulated.

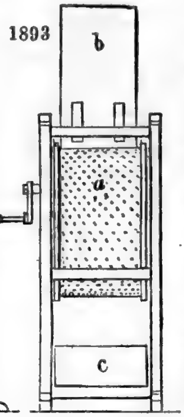
During the drying, starch splits into small prismatic columns, of considerable regularity. When kept dry, it remains unaltered for a very long period. When it is heated to a certain degree in water, the envelopes of its spheroïdal particles burst, and the farina forms a mucilaginous emulsion, magma, or paste. When this apparent solution is evaporated to dryness, a brittle, horny-looking substance is obtained, quite different in aspect from starch, but similar in chemical habitudes. When the moist paste is exposed for two or three months to the air in summer, the starch is converted into sugar, to the amount of one-third or one-half of its weight, into gum and gelatinous starch, called *amidine* by De Saussure, with occasionally a resinous matter. This curious change goes on even in close vessels.

Starch from Potatoes.—The potatoes are first washed in a cylindrical cage formed of wooden spars, made to revolve upon a horizontal axis, in a trough filled with water to the level of the axis. They are then reduced to a pulp by a rasping machine, similar to that represented in *figs.* 1892, 1893; where *a* is a wooden drum, covered with sheet iron, roughened outside with numerous prominences, made from punching out holes from the opposite side. It is turned by a winch fixed upon each end of the shaft. The drum is enclosed in a square wooden box, to prevent the potato-mash from being scattered about. The hopper, *b*, is attached to the upper frame, has its bottom concentric with the rasp-drum, and nearly in contact with it. The pulp-chest, *c*, is made to slide out, so as when full to be readily replaced by another. The two slanting boards, *d*, *d*, conduct the pulp into it. A moderate stream of water should be made to play into the hopper upon the potatoes, to prevent the surface of the rasp from getting foul with fibrous matter. Two men, with one for a relay, will rasp, with such a machine, from 2½ to 3 tons of potatoes in 12 hours.

1892



1893



The potato-pulp must be now elutriated upon a fine wire- or hair-sieve, which is set upon a frame in the mouth of a large vat, while water is made to flow upon it from a spout with many jets. The pulp meanwhile must be stirred and kneaded by the hand, or by a mechanical brush-agitator, till almost nothing but fibrous particles are left upon the sieve. These, however, generally retain about 5 per cent. of starch, which cannot be separated in this way. This parenchyma should therefore be subjected to a separate rasping upon another cylinder. The water, turbid with starch, is allowed to settle for some time in a back; the supernatant liquor is then run by a cock into a second back, and after some time into a third, whereby the whole starch will be precipitated. The finest powder collects in the last vessel. The starch thus obtained, containing 33 per cent. of water, may be used either in the moist state, under the name of *green fecula*, for various purposes, as for the preparation of dextrine and starch-syrup, or it may be preserved under a thin layer of water, which must be renewed from time to time, to prevent fermentation; or lastly, it may be taken out and dried.

Washing apparatus have been contrived by Lainé, Dailly, Huck, Vernies, Stolz, and St.-Etienne. These are contrivances for working very large quantities of potatoes in a short time. Huck's machine is stated to work 30,000 lbs. of potatoes daily, and in trials made with St.-Etienne's rasp and starch machinery, in Paris, which was driven by two horses, nearly 18 cwts. of potatoes were put through all the requisite operations in one hour, including the pumping of the water. The product in starch amounted to from 17 to 18 per cent. of the potatoes. The quicker the process of potato-starch making, the better is its quality. Völker proposed a process of rotting the potato to separate the starch.

Horse-chestnuts have been largely used at Nanterre, near Paris, in the manufacture of starch.

In the manufacture of potato-starch, a considerable quantity of the product is lost, owing to the strong affinity which the starch has for the fibre of the potato. M. Anthon stated some years ago that the manufacturer obtains only two-thirds of the starch, the remainder being left in the pulp. He suggested that this third may be utilised, by converting it into sugar by means of either malt or dilute sulphuric acid. By employing 10 per cent. of the acid to the dry fibre, the saccharification is complete in about two hours and a half; but if only 3 or 4 per cent. of acid is used, the boiling must be continued for at least 5 hours. Ten per cent. of malt effected the conversion in 6 hours. Mr. Calvert has given the following analysis of the potato:—Water, 74; starch, 20; the remainder being fibrous, earthy, and alkaline matters.

Starch from certain foreign plants.—1. From the pith of the *Sago Palm.* See SAGO.

2. From the roots of the *Maranta arundinacea*, of Jamaica, the Bahamas, and other West India Islands, the powder called arrow-root is obtained, by a process analogous to that for making potato-starch. See ARROW-ROOT.

3. From the roots of the *manioc*, which also grows in the West Indies, as well as in Africa, the *cassava* is procured, by a similar process. The juice of this plant is poisonous, from which the wholesome starch is deposited. When dried with stirring upon hot iron plates, it agglomerates into small lumps, called *tapioca*; being a gummy fecula. See CASSAVA.

The characters of the different varieties of starch can be learnt only from microscopic observation; by which means also their sophistication or admixture may be readily ascertained.

Starch, from whatever source obtained, is a white soft powder, which feels crispy, like flowers of sulphur, when pressed between the fingers; it is destitute of taste and smell, unchangeable in the atmosphere, and has a specific gravity of 1·53.

For the saccharine changes which starch undergoes by the action of *diastase*, see FERMENTATION.

Lichenine, a species of starch obtained from Iceland moss (*Cetraria islandica*), as well as *Inuline*, from elecampane (*Inula Helenium*), are rather objects of chemical curiosity than of manufactures. See LICHENS.

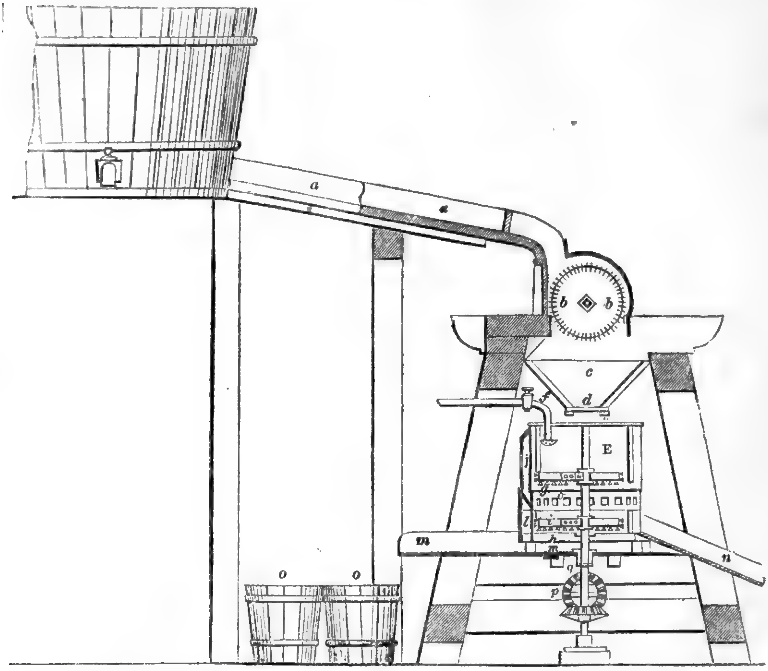
There is a kind of starch made in order to be converted into gum for the calico-printer. This conversion having been first made upon the great scale in this country, has occasioned the product to be called British gum. The following is the process pursued in a large and well-conducted establishment near Manchester:—A range of four wooden cisterns, each about 7 or 8 feet square and 4 feet deep, is provided. Into each of them 2,000 gallons of water being introduced, 12½ loads of flour are stirred in. The mixture is set to ferment upon old leaven left at the bottom of the backs, during 2 or 3 days. The contents are then stirred up, and pumped off into 3 stone cisterns, 7 feet square and 4 feet deep; as much water being added, with agitation, as will fill the cisterns to the brim. In the course of 24 hours the starch forms a firm deposit at the bottom; and the water is then syphoned off. The gluten is next scraped from the surface, and the starch is transferred into wooden boxes, pierced with holes, which may be lined with coarse cloth, or not, at the pleasure of the operator.

The starch, cut into cubical masses, is put into iron trays, and set to dry in a large apartment, two stories high, heated by a horizontal cylinder of cast iron traversed by the flame of a furnace. The drying occupies two days. It is now ready for conversion into gum, for which purpose it is put into oblong trays of sheet iron, and heated to the temperature of 300° Fahr. in a cast-iron oven, which holds four of these trays. Here it concretes into irregular semi-transparent yellow-brown lumps, which are ground into fine flour between mill-stones, and in this state brought to the market. In this roasted starch, the vesicles being burst, their contents become soluble in cold water. British gum is not convertible into sugar, as starch is, by the action of dilute sulphuric acid; nor into mucic acid, by nitric acid; but into the oxalic; and it is tinged purple red by iodine. It is composed, in 100 parts, of 35·7 carbon, 6·2 hydrogen, and 58·1 oxygen; while starch is composed of 43·5 carbon, 6·8 hydrogen, and 49·7 oxygen. See DEXTRINE.

Manufacture of Starch from Rice, &c.—Starch prepared from rice or maize by alkali is said not to require boiling—a point of great importance in its use; and, being less hygrometric than wheat-starch, retains a more permanent stiffness and glaze. The rough starch obtained in the process is valuable for feeding purposes, and for stiffening coarse fabrics.

Fig. 1894 represents in section the powerful and ingenious mechanical grater, or rasp (*râpe*), now used in France. *a a* is the canal, or spout, along which the previously well-washed potatoes descend; *b b* is the grater, composed of a wooden cylinder, on whose round surface circular saw rings of steel, with short sharp teeth, are planted pretty close together. The greater the velocity of the cylinder, the finer is the pulp. A cylinder 20 inches in diameter revolves at the rate of from 600 to 900 times a minute, and it will convert into pulp from 14 to 15 hectolitres (about 300 imperial gallons) of potatoes in an hour. Potatoes contain from 15 to 22 per cent. of dry fecula. The pulp, after leaving the rasp, passes directly into the apparatus for the preparation of the starch. *c* is a wooden hopper for receiving the falling pulp, with a trap-door, *d*, at bottom. E, is the cylinder-sieve of M. St.-Etienne; *f*, a pipe ending in a rose-spout, which delivers the water requisite for washing the pulp, and extracting the starch from it; *g g*, a diaphragm of wire-cloth, with small meshes, on which the pulp is exposed to the action of the brushes, *i i*, moving with great speed, whereby it gives out its starchy matter, which is thrown out by a side aperture into the spout *n*. The fecula now falls upon a second web of fine wire-cloth, and leaves upon it merely some fragments of the parenchyma or cellular matter of the potato, to be turned out by a side opening in the spout, *n*. The sifting or straining of the starch likewise takes place through the sides of the cylinder, which consists also of wire-cloth; it is collected into a wooden spout, *m*, and is thence conducted into the tubs *o o*, to be deposited and washed. *p* is a mitre-toothed wheel-work, placed on the driving-shaft, and gives motion to the upright axis or spindle, *q q*, which turns the brushes, *i, i*.

1894



STARCHING AND STEAM-DRYING APPARATUS. For a description of these processes, and of the machinery for accomplishing them, see BLEACHING and CALICO-PRINTING.

STATUARY PORCELAIN. See POTTERY.

STEAM is water in its vaporiform state. The varied and important applications of steam as a mechanical power would appear to render a consideration of its laws of the utmost importance. The circumstance that our spinning and weaving machinery, our pumping engines, our ships, our carriages, our hammers, our lathes, and our presses, are all moved by this power, seems to demand a full consideration of steam in a work devoted to *Arts, Manufactures, and Mines,* into each division of which it enters as an important element. But the limits assigned to the entire work renders it impossible to treat in any way commensurate with its importance this great mechanical power. It is, therefore, thought advisable to confine attention to a few general and well-established principles only. For especial information on the subject, the reader is referred to W. J. Macquorn-Rankine's 'Manual of the Steam-Engine;' Tredgold 'On the Steam-Engine;' De Pambour 'On the Theory of the Steam-Engine,' and 'On the Locomotive Engine;' Arago *Sur les Machines à Vapeur*; Regnault's papers in the *Mémoires* and *Comptes Rendus* of the Academy of Sciences, &c.

Steam is a chemical compound of oxygen and hydrogen, in the proportion of 8 parts by weight of oxygen, to 1 of hydrogen. Its composition by volume is such, that the quantity of steam which, if it were a perfect gas, would occupy 1 cubic foot at a given pressure and temperature, contains as much oxygen as would, if uncombined, occupy half a cubic foot, and as much hydrogen as would, if uncombined, occupy 1 cubic foot, at the same pressure and temperature; so that steam, if it were a perfect gas, would occupy two-thirds the space which its constituents occupy when uncombined. Hence is deduced the following composition of the weight of one cubic foot of steam would have at the temperature of 32° Fahr., and pressure of one atmosphere (or 14·7 lbs. on the square inch), if steam were a perfect gas, and if it could exist at the pressure and temperature stated.

Data from the Experiments of Regnault.

	b.
Half a cubic foot of oxygen at the pressure of one atmosphere and temperature, 32°	0·044628
1 cubic foot of hydrogen	0·005592
1 cubic foot of steam in the ideal state of perfect gas, at one atmosphere and 32°	0·050220

If steam were a perfect gas, the weight of a cubic foot could be calculated for any given pressure and temperature by the following formula:—

Weight of a cubic foot = 0·05022 lb. × pressure in atmosphere =

$$\times \frac{493\cdot{}^{\circ}2}{\text{Temp.} + 4\cdot61^{\circ}2}.$$

For example, at one atmosphere of pressure, and 212°, the weight of a cubic foot of steam would be:

$$0\cdot05022 \times \frac{493\cdot{}^{\circ}2}{673\cdot{}^{\circ}6} = 0\cdot03679 \text{ lb.}$$

But steam is known not to be a perfect gas; and its actual density is greater than that which is given by the preceding formula, though to what extent is not known by direct experiment. The most probable method of indirectly determining the density of steam, is by computation from the latent heat of evaporation, from which it appears that at one atmosphere and 212°, the weight of a cubic foot of steam is probably 0·03679 lb. The greatest pressure under which steam can exist at a given temperature is called the *pressure of saturation* for steam of a given temperature. The temperature is called the *boiling point* of water under the given pressure. The pressure of saturation is the only pressure at which steam and liquid water can exist together in the same vessel at a given temperature.

It becomes necessary to understand correctly the method of determining fixed temperatures by certain phenomena taking place at them. Thus ice begins to melt at a point, which we call the *freezing point*, marked 32° upon the scale devised by Fahrenheit (see THERMOMETER), and we determine the *boiling point* of water to be 212° on the same scale, under the average atmospheric pressure of 14·7 lbs. on the square inch; 2116·4 lbs. on the square foot; 29·992 inches of the column of mercury. At this latter point water ceases to be *liquid*, and becomes vaporiform. From 32° to 212°, all the heat which has been poured into the water has effected no change of physical condition, but the higher temperature being reached, a new condition is established, and steam is produced; this steam then beginning to act according to certain fixed laws.

A cubic inch of water evaporated under the ordinary atmospheric pressure is converted into a cubic foot of steam.

A cubic inch of water evaporated under the atmospheric pressure gives a mechanical force equal to what would raise a ton weight one foot high.

These are the effects produced at 212° under the above-named pressure.

Careful experiments have determined, within very small limits of error, the following facts:—Steam under pressure of 35 lbs. per square inch, and at the temperature of 261°, exerts a force equal to a ton weight raised one foot; under the pressure of 15 lbs. and at the temperature of 213°, it is 2,086 lbs., or about seven per cent. less; and under 70 lbs. and at 306° it is 2,382 lbs., or nearly six and a half per cent. more than a ton raised a foot. It is sufficient for all practical purposes to assume that each cubic inch evaporated, whatever be the pressure, develops a gross mechanical effort equivalent to a ton weight raised one foot.

As a given power is produced by a given rate of evaporation, to determine this the following rules are applicable:—

To produce the force expressed by one horse-power, the evaporation per minute must develop a mechanical force equal to 33,000 lbs., or about 15 tons raised 1 foot high. Fifteen cubic inches of water would accordingly produce this effect, which, without evaporation, would be equivalent to 900 cubic inches per hour. To find, therefore, the gross power developed by a boiler, it would be only necessary to divide the number of cubic inches of water evaporated per hour by 900. If, therefore, to 900 cubic inches be added the quantity of water per hour necessary to move the engine itself, independently of its load, we shall obtain the quantity of water per hour which must be supplied by the boiler to the engine for each horse-power, and this will be the same whatever may be the magnitude or proportions of the cylinder.

STEAM BOILERS. Did space allow of our entering on a consideration of this important subject, which it does not, it would not properly fall within the scope of this Dictionary: we therefore refer to the Dictionary of Engineering, and to Mr. W. Fairbairn's papers in the 'Transactions of the Royal Society.'

STEAM-ENGINE. Steam-engines are divided into *condensing* and *non-condensing*, corresponding with those which are worked by steam at *high-pressure* and at *low-pressure* respectively. The form of the engine is varied according as it is a *stationary*, a *locomotive*, or a *marine* engine. For descriptions of the various forms, the reader must be referred to special treatises upon the subject, such as Rankine 'On the Steam-Engine.'

STEARIC ACID. (*Talgsäure*, Ger.) Chevreul's discovery of the constitution of fats, led to the present processes for the manufacture of stearic acid. The original experiments were published in 1823, and Gay-Lussac, with Chevreul in 1825, took patents for the manufacture of fatty acids. Pure stearic acid is prepared, according to its discoverer, Chevreul, in the following way:—Make a soap by boiling a solution of potash and mutton-suet in the proper equivalent proportions; dissolve one part of that soap in 6 parts of hot water, then add to the solution 40 or 50 parts of cold water, and set the whole in a place whose temperature is about 52° Fahr. A substance falls to the bottom, possessed of pearly lustre, consisting of the bi-stearate and bi-margarate of potash; which is to be drained and washed upon a filter. The filtered liquor is to be evaporated, and mixed with a small quantity of acid necessary to saturate the alkali left free by the precipitation of the above bi-salts. On adding water to it afterwards, the liquor affords a fresh quantity of bi-stearate and bi-margarate. By repeating this operation with precaution, we finally arrive at a point when the solution contains no more of these solid acids, but only the oleic. The precipitated bi-salts are to be washed and dissolved in hot alcohol, of specific gravity 0·820, of which they require about 24 times their weight. During the cooling of the solution, the bi-stearate falls down, while the greater part of the bi-margarate, and the remainder of the oleate, remain dissolved. By repeatedly dissolving in alcohol, and crystallising, the bi-stearate will be obtained alone, as may be proved by decomposing a little of it in water at a boiling heat, with muriatic acid, letting it cool, washing the stearic acid obtained, and exposing it to heat, when, if pure, it will not fuse in water under the 158th degree of Fahrenheit's scale. If it melts at a lower heat, it contains more or less margaric acid. The purified bi-stearate being decomposed by boiling in water along with any acid, as the muriatic, the disengaged stearic acid is to be washed by melting in water, then cooled and dried.

Stearic acid, prepared by the above process, contains combined water, from which it cannot be freed. It is insipid and inodorous. After being melted by heat, it solidifies at the temperature of 158° Fahr., and affects the form of white brilliant needles grouped together. It is insoluble in water, but dissolves in all proportions in boiling anhydrous alcohol, and on cooling to 122°, crystallises therefrom in pearly plates; but if the concentrated solution be quickly cooled to 112°, it forms a crystalline mass. A dilute solution affords the crystallised acid in large white brilliant scales. It dissolves in its own weight of boiling ether of 0·727, and crystallises on cooling in beautiful scales, of changing colours. Its distils over *in vacuo* without alteration; but if the retort contains a little atmospheric air, a small portion of the acid is decomposed during the distillation; while the greater part passes over unchanged, but slightly tinged brown, and mixed with traces of empyreumatic oil. When heated in the open air, and kindled, stearic acid burns like wax. By analysis it is found to contain in 100 parts, carbon 75·6, hydrogen 12·6, and oxygen 11·8, which agrees with the formula $C^{36}H^{36}O^{4}$ ($\mathbf{C^{18}H^{36}O^{2}}$). Stearic acid displaces, at a boiling heat in water, carbonic acid from its combinations with the bases; but in operating upon an alkaline carbonate, a portion of the stearic acid is dissolved in the liquor before the carbonic acid is expelled. The decomposition is founded upon the principle, that the stearic acid transforms the salt into a bicarbonate, which is decomposed by the ebullition.

Of late years lime has been had recourse to, with perfect success, and has become subservient to a great improvement in candle-making. Lime was first successfully used by De Milley in 1831. The stearine block now made by many London houses, though containing not more than 2 or 3 per cent. of wax, is hardly to be distinguished from the purified produce of the bee. The first process is to boil the fat with quicklime and water in a large tub by means of perforated steam-pipes distributed over its bottom. About 11 parts of dry lime are fully equivalent to 100 of stearine and oleine mixed; but as the lime is in the state of hydrate, 14 parts of it will be required when it is perfectly pure; in the ordinary state, however, as made from average good limestone, 16 parts may be allowed. After a vigorous ebullition of 3 or 4 hours, the combination is pretty complete. The stearate being allowed to cool to such a degree as to admit of its being handled, becomes a concrete mass, which must be dug out with a spade, and transferred into a contiguous tub, in order to be decomposed with the equivalent quantity of sulphuric acid diluted with water, and also heated with steam. Four parts of concentrated acid will be sufficient to neutralise 3 parts of slaked lime. The saponified fat now liberated from the lime, which is thrown down to the bottom of the tub in a state of sulphate, is skimmed off the surface of the watery menstruum into a third contiguous tub, where it is washed with water and steam.

The washed mixture of stearic, margaric, and oleic acids, is next cooled in tin pans; then shaved by large knives fixed on the face of a fly-wheel, called a tallow-cutter, preparatory to its being subjected in canvas or caya bags to the action of a powerful hydraulic press. Here a large portion of the oleic acid is expelled, carrying with it a little of the margaric. The pressed cakes are now subjected to the action of water and steam once more, after which the supernatant stearic acid is run off, and cooled in moulds. The cakes are then ground by a rotatory rasping-machine to a sort of mealy powder, which is put into canvas bags, and subjected to the joint action of steam and pressure in a horizontal hydraulic press of a peculiar construction, somewhat similar to that which has long been used in London for pressing spermaceti. The cakes of stearic acid thus freed completely from the margaric and oleic acids, are subjected to a final cleansing in a tub with steam, and then melted into hemispherical masses called 'blocks.' When these blocks are broken, they display a highly crystalline texture, which would render them unfit for making candles. This texture is therefore broken down or comminuted by fusing the stearine in a plated copper pan, along with one-thousandth part of pulverised arsenious acid, after which it is ready to be cast into candles in appropriate moulds. See CANDLE.

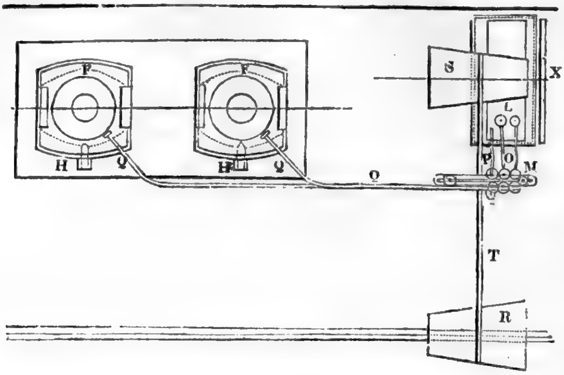
Moinier and Boutigny introduced a process by which the production of stearic acid has been considerably increased. Two tons of tallow and 900 gallons of water are introduced into a large rectangular vat of about 270 feet capacity. The tallow is melted by means of steam admitted through a pipe coiled round the bottom, and the whole kept at the boiling point for an hour, during which a current of sulphurous acid is forced in. At the end of this period 6 cwts. of lime, made into milk with 350 gallons of water, are added. The mixture soon acquires consistency, and becomes frothy and viscid. The whole is now agitated, in order to regulate the ebullitions and prevent the sudden swelling up of the soapy materials. The pasty appearance of the lime soap succeeds, and it then agglomerates into small nodular masses. The admission of sulphurous acid is now stopped; but the injection of the steam is continued until the small masses become hard and homogeneous. The whole period occupies eight hours, but the admission of sulphurous acid is discontinued at the end of about three hours. The water containing the glycerine is run off through a tube into cisterns prepared to receive it. The arrangements for producing sulphurous acid are retorts into which are put sulphuric acid and pieces of wood; upon the application of heat the sulphurous acid passes off, and is conveyed by leaden pipes into the vessel containing the tallow. The lime-soap formed is then moistened with 12 cwts. of sulphuric acid at 152° Fahr., diluted with 50 gallons of water. The whole is thoroughly agitated, and the steam cautiously admitted, so as not to dilute the acid too much until the decomposition is general at all points. This occupies about three hours, and in two or three hours more the sulphate of lime has collected at the bottom, while the fatty acids are floating on the surface of the solution of the sulphate of lime. Several processes of washing with steam and water are necessary to ensure the removal of the sulphate of lime, &c., and after settling for four hours, the fatty acids are forced through a fixed syphon into a vat, where they are again washed with water; they are then syphoned at last into a trough lined with lead, on the bottom of which are placed leaden gutters pierced below by long pegs of wood. The fatty acids are then placed in cloths, and subjected to pressure in the stearine cold press as described below.

It is important for the fatty acids to cool slowly, for thus the confused crystallisation is prevented, and the expulsion of the oleic acid facilitated. When the cakes are solid they are placed between sacks of horse-hair, and submitted to a second pressure at high temperature. The whole is covered with oil-skin, and the temperature raised to 158°·5 Fahr., when pressure is applied. The heat slowly falls to 113° Fahr., and ultimately reaches 95° to 80° Fahr. This operation lasts about an hour. The cakes of stearic acid are sorted according to colour and transparency, and about 20 cwts. are then introduced into a vat constructed of wood lined with sheet-iron. This is boiled by means of steam admitted through a leaden pipe, which is afterwards employed in heating a stove. Water acidulated is first employed, and afterwards pure water. When the materials are boiling, the whites of twenty-two eggs are introduced, and the albumen is intimately mixed by the violent ebullition. As soon as the albumen is coagulated, the whole is allowed to cool, and the stearic acid is removed to another apartment, where it is kept in a state of agitation to prevent the formation of crystals, and allow the cooling to be as gradual as possible. It is now fit for candles.

The cold hydraulic press, as mounted by Messrs. Maudslay and Field, for squeezing out the oleic acid from saponified fat, or the oleine from cocoa-nut lard, is represented in plan in *fig.* 1895, in side view of pump in *fig.* 1896, and in elevation, *fig.* 1897, where the same letters refer to like objects.

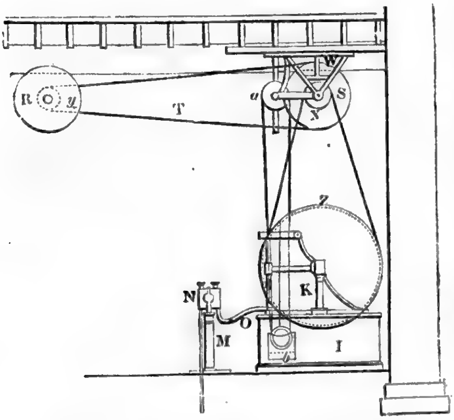
Scale of 3-20ths of an inch to the foot.

1895

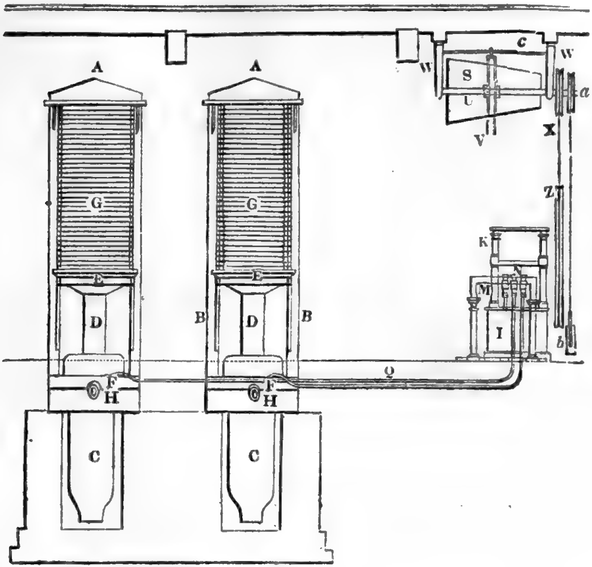


A, A, are two hydraulic presses; B, the frame; C, the cylinder; D, the piston or ram; E, the follower; F, the recess in the bottom to receive the oil; G, twilled woollen bags, with the material to be pressed, having a thin plate of wrought iron between each; H, apertures for the discharge of the oil; I, cistern in which the pumps are fixed; K, framing for machinery to work in; L, two pumps, large and small, to inject the water into the cylinders; M, a frame containing three double branches; N, three branches, each having two stops or plugs, by which the action of one of the pumps may be intercepted from, or communicated to, one or both of the presses; the large pump is worked at the beginning of the operation, and the small one towards the end; by these branches, one or both presses may be discharged when the operation is finished; O, two pipes from the pumps to the branches; P, pipe to return the water from the cylinders to the cisterns; Q, pipes leading from the pumps through the branches to the cylinders; R, conical drum, fixed upon the main shaft Y, driven by the steam-engine of the factory; S, a like conical drum to work the pumps; T, a narrow leather strap to communicate the motion from R to S; U, a long screw bearing a nut, which works along the whole length of the drum; V, the fork or guide for moving the strap T; W, W, two hanging bearings to carry the drum S; X, a pulley on the spindle of the drum S; Y, the main shaft; Z, fly-wheel with groove on the edge, driven by the pulley X; on the axis of S, is a double crank, which works the two pumps L. *a* is a pulley on the end of the long screw, U; an endless cord passes twice round this pulley, and under a pulley fixed in the weight, *b*; by laying hold of both sides of this cord, and raising or lowering it, the forked guide V, and the leather strap T, are moved backwards or forwards, by means of the nut fixed in the guide, so as to accelerate or retard at pleasure the speed of the working of the pumps; *c* is a piece of iron, with a long slit, in which a pin, attached to the fork V, travels, to keep it in the vertical position.

1896



1897



The accompanying *fig.* 1898, is a view both of the exterior and the interior of the saponifying tun of a stearine factory; where the constituents of the tallow are combined with quicklime, by the intervention of water and steam: *a* is the upright shaft of iron, turned by the bevel-wheel above, in gear with another bevel-wheel on the moving shaft, not shown in this figure. This upright shaft bears several arms, *d*, furnished with large teeth. The tun is bound with strong hoops of iron, and its contents are heated by means of a spiral tube laid on the bottom, perforated with numerous holes, and connected by a pipe with a high-pressure steam-boiler.

1898

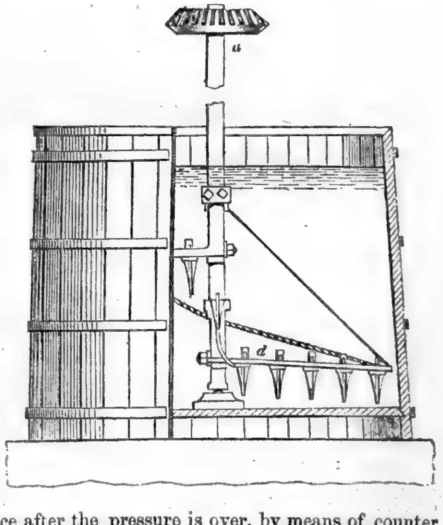
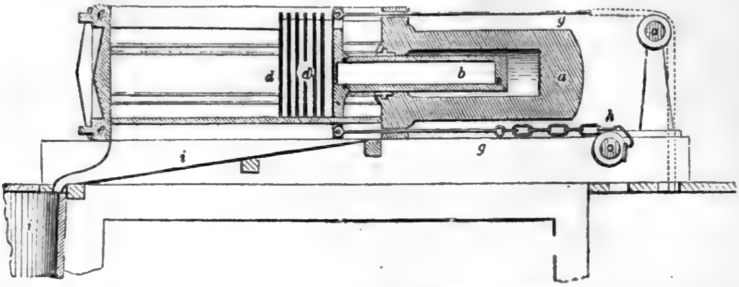


Fig. 1899 (next page) represents a longitudinal section of the horizontal hydraulic press for depriving stearic acid, as also spermaceti, of all their fluid oily impurities. *a* is the cylinder of the press; *b*, the ram or piston; *d d*, iron plates previously heated, inclosing hair and flannel bags and placed between every two cakes to facilitate the discharge of their oily matter; *e*, *e*, solid iron end of the press, made to resist great pressure; it is strongly bolted to the cylinder *a*, so as to resist the force of the ram; *g*, *g*, are rods for bringing back the ram *b* into its place after the pressure is over, by means of counter weights suspended to a chain, which passes over the pulleys *h*, *h*; *i*, *i*, a spout and a sheet-iron pan for receiving the oily fluid.

STEARINE (from Gr. *στέαρ*, *stear*, 'tallow'). The solid portions of fats are known by this term, the fluid portions being called *oleine*, from ἔλαιον, *elaion*, 'oil.' If melted tallow be dissolved in about eight times its weight of ether, on cooling the oleine alone remains dissolved, the stearine crystallises, and can be rendered absolutely pure by washing with ether. Stearine is a solid transparent substance, easily reduced to powder. At one time stearine was an object of manufacture; but the production of stearic acid has superseded it.

1899



We Imported in 1873 *the following quantities of Stearine and Tallow:—*

	Cwts.	Value
		£
From Russia	210,009	448,118
„ Holland	6,779	20,224
„ France	7,019	21,331
„ United States of America	493,138	1,012,102
„ Brazil	33,134	67,808
„ Uruguay	144,860	303,962
„ Argentine Republic	319,918	651,999
„ Australia	290,107	580,829
„ British North America	11,957	23,517
„ Other countries	10,400	22,523
Total	1,527,321	3,152,413

STEATITE, or *Soapstone* (*Speckstein*, Ger.), is a massive variety of *talc.* It has a greyish-white or greenish-white colour, often marked with dendritic delineations, and occurs massive; it has a dull or fatty lustre; a coarse splintery fracture, with translucent edges; a shining streak; it writes feebly; is soft, and easily cut with a knife, but somewhat tough; does not adhere to the tongue; feels very greasy; infusible before the blowpipe; specific gravity from 2·6 to 2·8. It is found frequently in small contemporaneous veins traversing serpentine in all directions, as at Portsoy in Shetland, in the limestone of Icolmkiln, in the serpentine of Cornwall, in Anglesey, in Saxony, Bavaria (at Bayreuth), Hungary, &c. The chemical composition of steatite is silica 62·14, magnesia 32·92, water 4·94, being sometimes contaminated with and coloured with a little iron, manganese, or chrome. It is occasionally used in the manufacture of porcelain. It makes the biscuit semi-transparent, but rather brittle, and apt to crack with slight changes of heat. It is employed for polishing serpentine, marble, gypseous alabaster, and mirror-glass; as the basis of cosmetic powder; and as an ingredient in anti-attrition pastes, sold under the name of *French Chalk*; it is dusted in powder upon the inside of boots, to make the feet glide easily into them; when rubbed upon grease-spots in silk and woollen clothes, it removes the stains by absorption; it enters into the composition of certain crayons, and is used itself for making traces upon glass, silk, &c. The spotted steatite, cut into cameos and calcined, assumes an onyx aspect. Soft steatite forms excellent stoppers for the chemical apparatus used in distilling or subliming corrosive vapours. Lamellar steatite is *talc* See TALC.

STEEL (*Acier*, Fr.; *Stahl*, Ger.) is a carburet of iron, more or less freed from foreign matter, and may be produced by two processes opposed to each other: first, by working pig-iron, which contains 4 to 5 per cent. of carbon, in a suitable furnace, until such carbon is reduced to the quantity required for constituting steel, which is about 1 per cent.; the second method is to heat iron bars in contact with charcoal, until they have absorbed that quantity of carbon which may be required.

Steel may be classed into three kinds:

1st. Natural steel, which is manufactured from pig-iron direct.

2nd. Cemented or converted steel, which is produced by the carbonisation of wrought iron.

3rd. Cast-steel which is produced by the fusion of either natural or cemented steel, but principally from the latter.

The various kinds of iron which are used for the manufacture of steel were formerly imported from Sweden, Norway, and Russia; but the high price of Swedish and other steel-iron has compelled the consumers to look elsewhere for a supply of suitable iron, and to offer every encouragement to English manufacturers so to improve their steel-irons as to render them suitable for the production of steel.

England now furnishes a large quantity of iron suitable for steel purposes, which may be estimated at 20,000 tons per annum; this iron is manufactured with great care, often with an admixture of charcoal pig-iron, and various chemical reagents, which are added at the caprice of each manufacturer.

It is of the highest importance that the iron used for steel purposes should be as pure as possible; those irons which have long enjoyed the highest reputation are manufactured from the Dannemora ores in Sweden; the whole of the steel-irons produced in that country are smelted from the magnetic and red oxides containing usually 60 per cent. of metal.

Natural or German steel is so called because it is produced direct from pig-iron, the result of the fusion of the spathose iron ores alone, or in a small degree mixed with the brown oxide. This crude-iron contains 4 to 5 per cent. of carbon and 4 to 5 per cent. of manganese. Karsten, Hassenfratz, Marcher, and Réaumur, all advocate the use of grey pig-iron for the production of steel; indeed they distinctly state that the best qualities cannot be produced without it; they state that the object of working it in the furnace is to clear away all foreign matters, but there can be no advantage gained by retaining the carbon and retaining it with the iron. The theory is incorrect, although it is supported by such high authorities. Grey-iron contains the maximum quantity of carbon, and consequently remains for a longer time in a state of fluidity than iron containing less carbon; the metal is not only mixed up with the foreign matter it may itself contain, but also that with which it may become mixed in the furnace in which it is worked. This prolonged working, which is necessary in order to bring highly-carbonised metal into a malleable state, increases the tendency to produce silicated oxides of iron; which mixing with the steel produced renders it 'red short,' and destroys many good qualities which the pig-iron may have originally possessed. In Austria, where a large quantity of natural steel is produced, the fluid metal is tapped from the blast-furnace into a round hole; water is sprinkled on the surface which chills it, and thus forms a cake about half an inch thick. This is taken from the surface, and the operation is again performed until the whole is formed into cakes, they are then piled edgewise in a furnace, and covered with charcoal, and heated to a full red heat for about 48 hours; by this process much of the carbon is discharged. These cakes are then used for producing steel in the refinery. A much superior quality is thus obtained with greater economy. It appears that the most perfect plan for manufacturing the steel is to free the crude metal as much as possible from its impurities whilst in a fluid state. The furnaces used for the production of natural steel are like the refineries in which charcoal-iron is produced. In all countries their *general* construction is the same, but each has its own peculiar mode of working. We find therefore, the German, the Styrian, the Carinthian, and several other distinct methods, yet all producing steel from crude-iron directly, although pursuing different modes of operation. These differences arise from the nature of the pig-iron each country produces, and the peculiar habits of the workmen. These modified processes do not affect the *theory* of the manufacture of the steel, but rather accommodate themselves to the peculiar character of the metal produced.

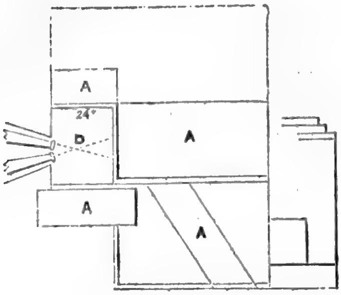
Fig. 1900 shows a ground-plan of the furnace; *fig*, 1901 an elevation; and *fig.* 1902 the form of the fire itself and the position of the metal within it. The fire, D, is 24 inches long and 24 inches wide; A, A, A, are metal plates, surrounding the furnace.

Fig. 1901 shows the elevation, usually built of stone, and braced with iron bars. The fire, G, is 16 inches deep and 24 inches wide; before the tuyère, at B, a space is left under the fire, to allow the damp to escape, and thus keep the bottom dry and hot.

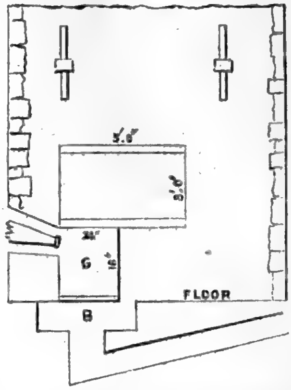
In *fig.* 1902 there are two tuyères, but only one tuyère iron, which receives both the blast nozzles, which are so laid and directed that the currents of air cross each other, as shown by the dotted lines; the blast is kept as regular as possible, so that the fire may be of one uniform heat, whatever intensity may be required.

Fig. 1902 shows the fire itself, with the metal, charcoal, and blast. A is a bottom of charcoal, rammed down very close and hard. B is another bottom, but not so closely beaten down; this bed of charcoal protects the under one, and serves also to give out carbon to the loop of steel during its production. C is a thin stratum of metal, which is kept in the fire to surround the loop. D shows the loop itself in progress.

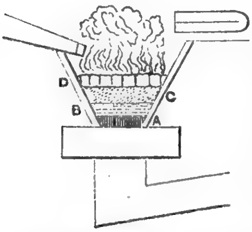
1900



1901



1902



When the fire is hot, the first operation is to melt down a portion of pig-iron, say 50 to 70 pounds according as the pig contains more or less carbon; the charcoal is pushed back from the upper part of the fire, and the blast, which is then reduced, is allowed to play upon the surface of the metal, adding from time to time some hammer-slag, or rich cinder, the result of the previous loop. All these operations tend to *decarbonise* the metal to a certain extent; the mass begins to thicken, and at length becomes solid. The workman then draws together the charcoal and melts down another portion of metal upon the cake; this operation renders the face of the cake again fluid, but the operation of decarbonisation being repeated in the second charge, it also thickens, incorporates itself with the previous cake, and the whole becomes hard; metal is again added until the loop is completed. During these successive operations, the loop is never raised before the blast, as it is in making iron, but it is drawn from the fire and hammered into a large bloom, which is cut into several pieces, the ends being kept separated from the middle or more solid parts, which are the best.

This operation, apparently so simple in itself, requires both skill and care; the workman has to judge, as the operation proceeds, of the amount of carbon which he has retained from the pig-iron; if too much, the result is a very raw, crude, untreatable steel; if too little, he obtains only a steelified iron; he has also to keep the cinder at a proper degree of fluidity, which is modified from time to time by the addition of quartz, old slags, &c. It is usual to keep from two to three inches of cinder on the face of the metal, to protect it from the direct action of the blast. The fire itself is formed of iron plates, and the two charcoal-bottoms rise to within nine inches of the tuyère, which is laid flatter than when iron is being made. This position of the tuyère causes the fire to work more slowly, but it ensures a better result.

The quantity of blast required is about 180 cubic feet per minute. Good workmen make 7 cwts. of steel in 17 hours. The waste of the pig-iron is from 20 to 25 per cent., and the quantity of charcoal consumed is 240 bushels per ton. The inclination of the tuyère is 12 to 15 degrees. The flame of the fire is the best guide for the workmen. During its working it should be a red bluish colour. When it becomes white the fire is working too hot.

When, care has been taken in melting down each portion of metal, and a complete and perfect layer of steel has been obtained after each successive melting, when the cinder has had due attention, so that it has been neither too thick nor too thin, and the heat of the fire regulated and modified during the progressive stages of the process, then a good result is obtained; a fine-grained steel is produced, which draws under the hammer, and hardens well. However good it may be it possesses one great defect; it is this. During its manufacture, *iron* is produced along with the steel, and becomes so intimately mixed up with it, that it injures the otherwise good qualities of the steel; the iron becomes, as it were, interlaced throughout the mass, and thus destroys its hardening quality. When any tool or instrument is made from natural steel, unless it has been well refined, it will not receive a *permanent* cutting edge; the iron part of the mass, of course, not being hard, the tool cuts only upon the steel portion; the edge, therefore, very soon becomes destroyed. There is another defect in natural steel, but it is of less importance. When too much carbon has been left, the steel is raw and coarse, and it draws very imperfectly under the hammer; the articles manufactured from such steel often break in hardening; thus it is evident, that in producing this kind of steel, every care, skill, and attention is required at the hands of the workman.

The raw steel, being imperfect, is not considered so much an article of commerce with the manufacturer, but it is sold to the steel-refiners, who submit it to a process of welding. The raw steel-bloom is drawn into bars one or two inches wide and half an inch thick, or less; a number of these are put together and welded; these bars are then thrown into water, and they are broken in smaller pieces to examine the fracture; those bars which are equally steelified are mixed together. In manufacturing refined steel, the degree of hardness is selected to suit the kind of article which it is intended to make. A bar, two to three feet long, forms the top and bottom of the bundle, but the inside of the packet is filled with the small pieces of selected steel. This packet is then placed in a hollow fire, and carefully covered from time to time with pounded clay, to form a coat over the metal, and preserve it from the oxidising influence of the blast. When it is at a full welding heat it is placed under a hammer, and made as sound and homogeneous as possible; it is again cut, doubled together, and again welded. For very fine articles, the refining is increased by several doublings, but this is not carried at present to so great an extent as formerly, since cast steel is substituted, being in many cases cheaper.

Natural steel being expensive, many attempts were made in Westphalia to produce a kind of steel by puddling pig-iron in a peculiar manner; a patent was taken out in England by Mr. Riepe, and a considerable quantity of this steel was produced. In Mr. Riepe's description of this process, he says:—

'I employ the puddling furnace in the same way as for making wrought iron. I introduce a charge of about 280 lbs. of pig-iron, and raise the temperature to redness. As soon as the metal begins to fuse and trickle down in a fluid state, the damper is to be partially closed in order to temper the heat. From 12 to 16 shovelsful of iron cinder discharged from the rolls or squeezing machine are added, and the whole is to be uniformly melted down. The mass is then to be puddled with the addition of a little black oxide of manganese, common salt, and dry clay, previously ground together. After this mixture has acted for some minutes, the damper is to be fully opened, when about forty pounds of pig-iron is to put into the furnace, near the fire-bridge, upon elevated beds of cinder prepared for that purpose. When this pig-iron begins to trickle down, and the mass on the bottom of the surface begins to boil and throw out from the surface the well-known blue jets of flame, the said pig-iron is raked into the boiling mass, and the whole is then well mixed together. The mass soon begins to swell up, and the small grains begin to form in it and break through the melted cinder on the surface. As soon as these grains appear, the damper is to be three-quarters shut, and the process closely inspected while the mass is being puddled to and fro beneath the covering layer of cinder. During the whole of this process the heat should not be raised above cherry-redness, or the welding heat of shear-steel. The blue jets of flame gradually disappear, while the formation of grains continues, which grains very soon begin to fuse together, so that the mass becomes waxy, and has the above-mentioned cherry redness. If these precautions are not observed, the mass would pass more or less into iron, and no uniform steel product could be obtained. As soon as the mass is finished so far, the fire is stirred to keep the necessary heat for the succeeding operation: the damper is to be entirely shut, and part of the mass is collected into a ball, the remainder always being kept covered with cinder slack. This ball is brought under the hammer, and then worked into bars. The same process is continued until the whole is worked into bars. When I use pig-iron made from sparry iron ore, or mixtures of it with other pig-iron, I add only about 20 lbs. of the former pig-iron at the later period of the process, instead of about 40 lbs. When I employ Welsh or pig-iron of that description, I throw 10 lbs. of best plastic clay, in a dry granulated state, before the beginning of the process, on the bottom of the furnace. I add, at the later period of the process, about 40 lbs. of pig-iron as before described, but strew over it clay in the same proportion as just mentioned.'

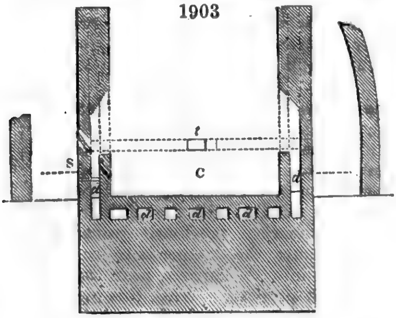
This steel is very useful for ships' plates, being very strong and rigid, and thus requiring less weight of metal; it may also eventually be used for rails and a great variety of purposes, for which at present strong charcoal or scrap iron is used.

The Paal process may be considered as an improvement upon natural steel, the object being as far as possible to carbonise the iron fibres which this kind of steel always contains. The process is based upon the old one of Vanaccio: it consists in plunging iron into a bath of melted metal. The carbon of the metal combines with the iron, and in a very short time converts it into steel. This process was carried further by Vanaccio, who contrived to add wrought iron to the metal until he had decarbonised it sufficiently; this was found to produce a steel, but unfit for general use. That produced by plunging iron into metal was found to be a very hard steel on the outside, but iron within; while that produced by adding iron to the metal was found too brittle to be drawn. The Paal method, however, was a decided improvement in the manufacture of refined natural steel. The packets, as already described in the refinement of natural steel, are welded and drawn to a bar; whilst hot they are plunged into a bath of metal for a few minutes, by which the iron contained in the raw steel becomes carbonised, and thus a more regular steel is obtained than that produced by the common process. The operation requires great care, for if the bars of steel be left in the metal too long they are more or less destroyed, or perhaps entirely melted.

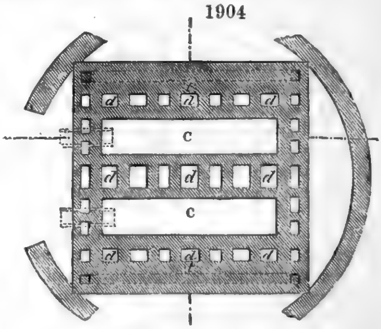
The foregoing kinds of steel may be classed under the first head of natural steel, being manufactured from the *crude iron direct.*

The next process is the production of steel by introducing carbon into malleable iron which is the reverse of the process already described. The iron to be converted is placed in a furnace, stratified with carbonaceous matter, and on heat being applied the iron absorbs the carbon, and a new compound is thus formed.

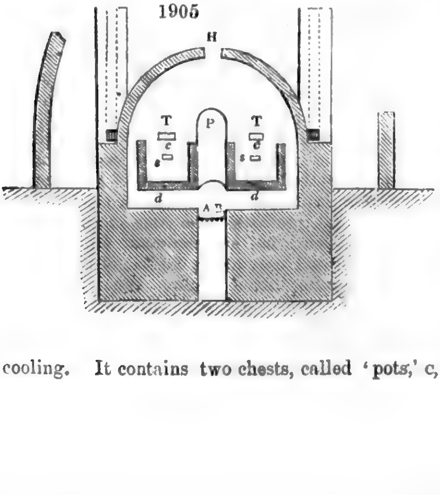
1903



1904



1905



At a very early period charcoal was found to harden iron, and to give it a better and more permanent cutting edge. It seems probable that from hardening small objects bars of iron were afterwards submitted to the same process. To Réaumur certainly belongs the merit of first bringing the process of conversion to any degree of perfection. His work contains much information on the theory of cementation; and although his investigations are not borne out by the practice of the present day, yet the first principles laid down by him are now the guide of the converter. Our furnaces are much larger than those used by Réaumur, and they are built so as to produce a more uniform and economical result. The furnace of cementation in which bar iron is converted into blistered steel is represented in *figs.* 1903, 1904, and 1905.

It is rectangular, and covered in by a semicircular arch, in the centre of which there is a circular hole left, 12 inches diameter, which is opened when the furnace is cooling. It contains two chests, called 'pots,' C, C, made either of fire-stone or fire-bricks: each 'pot' is 3 feet wide, 3 feet deep, and 12 feet long. One is placed on one side, and the other, on the contrary side of the fire-grate, A B, which occupies the whole length of the furnace, and is 13 to 14 feet long; the grate is 15 to 16 inches broad, and the bars rest from 10 to 12 inches below the inferior plane or bottom level of the 'pots;' the height of the arch at the centre is 5½ feet above the top of the 'pots,' the bottoms of which are nearly level with the ground, so that the bars of iron do not need lifting so high when charging them into the furnace. The flame rises between the two 'pots;' it passes also below and around them, through the horizontal and vertical flues, *d*, and issues from the furnace through the six small chimneys, H, into a large conical space which is built around the whole furnace, 30 to 40 feet high, open at the top. This cone increases the draft of the furnace, and carries away the smoke. There are three openings in the front of the arch: two, T, *fig.* 1905, above the pots serve to admit and remove the bars; they are about 8 inches square; in each a piece of iron is placed upon which the bars slide in and out of the furnace. The workman enters by the middle opening, P, to arrange the bars, which he lays flat in the pots and spreads a layer of charcoal, ground small, between each layer; the bars are laid near each other, excepting those next to the side of the pot, which are placed an inch from it; the last stratum of iron is covered with a thick layer of charcoal, and the whole is carefully covered with loamy earth, 4 to 5 inches thick. The iron is gradually heated; in about four days it has become fully heated through, and the furnace has then attained its maximum heat, which is maintained for 2 or 3 days, until the first test bar is drawn out; the heat is afterwards regulated, according to the degree of hardness which may be required. The iron is converted in 8 days if for soft steel, and in 9 to 11 days if for harder purposes.

Conversion usually commences in 60 to 70 hours after the furnace is lighted. The pores of the iron being opened by heat, the carbon is gradually absorbed by the mass of the bar, but the *carbonisation* or conversion is effected, as it were, in layers. To explain the theory in the clearest manner, suppose a bar to be composed of a number of laminæ; the combination of the carbon with the iron is first effected on the surface, and gradually extends from one lamina to another, until the whole is carbonised. To effect this complete carbonisation, the iron requires to be kept at a considerable uniform heat for a length of time. Thin bars of iron are much sooner converted than thick ones. Réaumur states, in his experiments, that if a bar of iron $\frac{7}{16}$ths of an inch thick is converted in 9 hours, a bar $\frac{3}{16}$ths of an inch would require 36 hours to attain the same degree of hardness. The carbon introduces itself *successively*, the first lamina or surface of a bar combining with a portion of the carbon with which it is in contact, gives a portion of the carbon to the second lamina, at the same time taking up a fresh quantity of carbon from the charcoal; these successive combinations are continued until the whole thickness is converted: from which theory it is evident that from the exterior to the centre the dose of carbon becomes proportionately less. Steel so produced cannot be said to be perfect; it possesses in some degree the defect of natural steel, being more carbonised on the surface than at the centre of the bar. From this theory we perceive that steel made by cementation is different in its character from that produced directly from crude metal. In conversion the carbon is made successively to penetrate to the centre of the bar, whilst in the production of natural steel, the molecules of metal which compose the mass are *per se* charged with a certain percentage of carbon necessary for their steelification; not imbibed, but obtained by the decarbonisation of the crude iron down to a point requisite to produce steel.

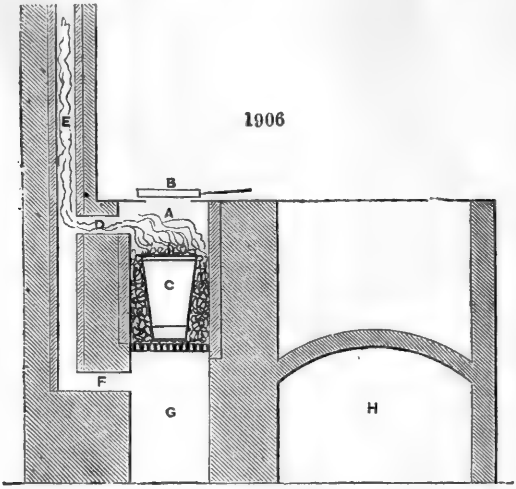
Bar steel is also used for manufacturing shear steel. It is heated, drawn to lengths 3 feet long, then subjected to a welding heat, and some six or eight bars are welded together, precisely as described in the refinement of natural steel; this is called single shear. It is further refined by doubling the bar, and submitting it to a second welding and hammering; the result is a clearer and more homogeneous steel. During the last few years the manufacture of this steel has been limited, mechanics preferring a soft cast steel, which is much superior, when properly manufactured, and which can be very easily welded to iron.

The process of melting bar steel, and thus producing cast steel, was first practically carried on by Mr. Huntsman of Attercliffe: the process itself is very simple. *Fig.* 1906 shows a cross section of the furnace commonly used.

The furnace A, is square, lined with fire-stone 12 inches by 22 wide, and 36 inches deep from the grate-bar to the under side of the cover B. C is a crucible, of which two are placed in one 'melting-hole.' D is the flue into the chimney, E, which is about 40 feet high, lined with fire-brick. There is an air-flue, which is used to regulate the draught at F. G is the ashpit, and H the cellar which is arched over.

The steel is broken in pieces and charged into the crucible, which is placed on a stand and provided with a cover; coke is used as a fuel, and an intense heat is obtained. The crucible is charged three times during the day, and is then burnt through; the first charge is usually 36 lbs.; which requires from 3 to 4 hours to melt it; the second charge is about 32 lbs., which is melted in about 3 hours; the last charge is 29 to 30 lbs., which does not require more than 2 to $2\frac{1}{2}$ hours to become perfectly melted. The consumption of coke averages $3\frac{1}{2}$ tons per ton of cast steel. When the steel is completely fluid the crucible is drawn from the furnace, and the steel poured into a cast-iron mould; the result is an ingot, which is subsequently rolled or hammered according to the wants of the consumer.

1906



Although the melting of cast steel is a simple process, yet, on the other hand, the manufacture of cast steel suitable for the various wants of those who consume it requires an extensive knowledge.

1907

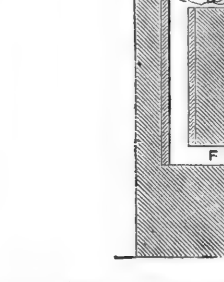


Fig. 1907 represents the mould for making the crucibles used for melting cast steel. Each manufacturer makes his own; M, M, is a solid block of wood let into the floor, having a hole which admits a round piece of iron fixed in the centre of the plug P. The material of which the crucible is made consists of 22 lbs. of fire-clay got from Stannington, near Sheffield, from the neighbourhood of Burton-on-Trent, or Stourbridge; 2 lbs. of the old crucible after it has been used, ground to powder, and about $\frac{1}{2}$ lb. of ground coke. These quantities are sufficient for one crucible of the ordinary size. This composition is trodden for 8 or 10 hours on a metal-floor; it is then cut into pieces of 26 to 28 lbs.; each piece is rolled round nearly to the size of the mould into which it is introduced, and the plug P is driven down with a mallet; the mould is furnished with a moveable bottom: when the pot is made, the mould is lifted up by the two handles, and fixing the bottom on a post, the mould falls, and leaves the crucible upon it.

Cast steel may be wanted for the engraver. It may be produced apparently perfect, and with a clear surface, but may be so improperly manufactured, that when the plate has been engraved and has to be hardened, it is found covered with soft places. The trial is even greater when the engraving is transferred by pressure to another plate. It is, therefore, evident that a steel-maker must not only attend to the intrinsic quality of his steel, but he has to use his judgment as regards the degree of hardness and tenacity which it should possess.

In manufacturing the commoner description of steel, particularly cast steel made from English iron, black oxide of manganese may be added to the steel in the crucible, and acts as a detergent. The oxygen unites with a portion of the carbon in the steel, forming carbonic oxide gas, which acts upon the imperfectly metallic portions of the steel used, and liberates the metal whilst the deleterious matter is taken up and forms a slag with the manganese. There has been a great controversy regarding the invention which originated with Mr. Heath. This substance is not generally used when the Dannemora irons are melted, as they are very pure, and the addition of an oxide partially destroys the temper of the steel.

Indian Steel, or Wootz.—The wootz ore consists of the magnetic oxide of iron, associated with quartz in proportions which do not seem to differ much, being generally about 42 of quartz and 58 of magnetic oxide. Its grains are of various size, down to a sandy texture. The natives prepare it for smelting by pounding the ore, and winnowing away the stony matrix, a task at which the Hindoo females are very dexterous. The manner in which iron ore is smelted and converted into wootz or Indian steel, by the natives at the present day, is probably the very same that was practised by them at the time of the invasion of Alexander; and it is a uniform process from the Himalaya Mountains to Cape Comorin. The furnace or bloomery in which the ore is smelted is from 4 to 5 feet high; it is somewhat pear-shaped, being about 2 feet wide at bottom, and 1 foot at top; it is built entirely of clay, so that a couple of men can finish its erection in a few hours, and have it ready for use the next day. There is an opening in front about a foot or more in height, which is built up with clay at the commencement, and broken down at the end of each smelting operation. The bellows are usually made of a goat's-skin, which has been stripped from the animal without ripping open the part covering the belly. The apertures at the legs are tied up, and a nozzle of bamboo is fastened in the opening formed by the neck. The orifice of the tail is enlarged and distended by two slips of bamboo. These are grasped in the hand, and kept close together in making the stroke for the blast; in the returning stroke they are separated to admit the air. By working a bellows of this kind with each hand, making alternate strokes, a pretty uniform blast is produced. The bamboo nozzles of the bellows are inserted into tubes of clay, which pass into the furnace at the bottom corners of the temporary wall in front. The furnace is filled with charcoal, and a lighted coal being introduced before the nozzles, the mass in the interior is soon kindled. As soon as this is accomplished, a small portion of the ore, previously moistened with water, to prevent it from running through the charcoal, but without any flux whatever, is laid on the top of the coals, and covered with charcoal to fill up the furnace.

In this manner ore and fuel are supplied; and the bellows are urged for 3 or 4 hours, when the process is stopped; and the temporary wall in front being broken down, the bloom is removed by a pair of tongs from the bottom of the furnace. It is then beaten with a wooden mallet, to separate as much of the scoriæ as possible from it, and while still red hot, it is cut through the middle, but not separated, in order merely to show the quality of the interior of the mass. In this state it is sold to the blacksmiths, who make it into bar iron, The proportion of such iron made by the natives from 100 parts of ore is about 15 parts. In converting the iron into steel, the natives cut it into pieces, to enable it to pack better in the crucible, which is formed of refractory clay mixed with a large quantity of charred husk of rice. It is seldom charged with more than a pound of iron, which is put in with a proper weight of dried wood chopped small, and both are covered with one or two green leaves; the proportions being in general 10 parts or iron to 1 of wood and leaves. The mouth of the crucible is then stopped with a handful of tempered clay, rammed in very closely, to exclude the air. The wood preferred is the *Cassia auriculata*, and the leaf that of the *Asclepias gigantea* or the *Convolvulus laurifolius*. As soon as the clay plugs of the crucibles are dry, from twenty to twenty-four of them are built up in the form of an arch, in a small blast furnace; they are kept covered with charcoal, and subjected to heat urged by a blast for about two hours and a half, when the process is considered to be complete. The crucibles being now taken out of the furnace and allowed to cool, are broken, and the steel is found in the form of a cake, rounded by the bottom of a crucible. When the fusion has been perfect, the top of the cake is covered with striæ, radiating from the centre, and is free from holes and rough projections; but if the fusion has been imperfect, the surface of the cake has a honeycomb appearance, with projecting lumps of malleable iron. On an average, four out of five cakes are more or less defective. These imperfections have been tried to be corrected in London by remelting the cakes, and running them into ingots; but it is obvious that when the cakes consist partially of malleable iron and of unreduced oxide, simple fusion cannot convert them into good steel. When care is taken, however, to select only such cakes as are perfect, to remelt them thoroughly, and tilt them carefully into rods, an article has been produced which possesses all the requisites of fine steel in an eminent degree.

The natives prepare the cakes for being drawn into bars by annealing them for several hours in a small charcoal furnace, actuated by bellows; the current of air being made to play upon the cakes while turned over before it; whereby a portion of the combined carbon is probably dissipated, and the steel is softened; without which operation, the cakes would break in the attempt to draw them. They are drawn by a hammer of a few pounds weight.

Hardening and *tempering* steel is a delicate operation. Small articles of cutlery are usually hardened by first heating them to a red heat and plunging them in water; saws and such articles are, when heated, plunged into oil. All articles are tempered by carefully heating them when hardened, and the degree of temper is indicated by a change in the colour of the surface, which is first straw-coloured, then blue, and deep blue: colour is thus made the most delicate test for the degree of temper given: after this operation, steel is found to expand a little. Alloys of steel have been very carefully made by Messrs. Stoddart and Faraday; but it can hardly be said that any alloy has at present been found to give any addition to the intrinsic quality of steel. The empiric titles of 'silver steel,' 'meteoric steel,' &c., may be regarded simply as fanciful names to recommend the article, either as a raw material, or in a manufactured state.

Those articles called 'run steel' are made by melting pig-iron and pouring it into moulds of sand in which the required article has been moulded; they are then packed in round iron pots, about 12 inches diameter and 16 to 18 inches high, along with hæmatite iron ore crushed to powder; these pots are packed in a furnace, and heat is applied from 24 hours to several days; the oxygen abstracts the carbon from the metal of which the articles are made, and they become to a certain extent malleable, so much so, that pieces a quarter of an inch thick may be bent almost double, and can be drawn out under a hammer. Forks, table-knives, scissors, and many other cheap articles are so made; also a vast variety of parts of cotton and flax machinery are so manufactured, especially those parts which are difficult to forge.

'Damascus' or 'damasked steel' is made by melting together iron and steel, or bars of steel of high and low degrees of carbonisation; it may also be produced by melting hard and soft steel in separate crucibles, mixing them together whilst fluid, and immediately pouring the mixture into an ingot mould; the damask is shown by the application of dilute acid to the surface when brightened. The analysis of a genuine Damascus sword-blade has shown that it is not a homogeneous steel, but a mixture of steel and iron.

Bessemer's Steel.—The undoubted success, and therefore the general adoption of this process for converting iron into steel, which derives its name from its inventor, renders it necessary that a full description of the process should be given.

The facility which the blast-furnace affords, of at once separating from the ores of iron the greater part of the extraneous matters which they contain, has rendered its employment almost universal, as a preliminary process in the production of malleable iron.

The crude metal thus obtained, although separated from a large proportion of its impurities, is nevertheless found to be intimately combined with carbon and silicum, and generally with sulphur, phosphorus, manganese, and some other substances, in comparatively minute quantities; the decarbonisation of the iron, and the separation of these substances, as far as is practicable, claims the first care of the manufacturer. For this purpose the crude metal is either formed into pigs, which are afterwards remelted in the 'finery furnace,' or it is run, while still in a fluid state, from the blast-furnace direct into the finery fire, where it is subjected to the action of blasts of air, directed downwards upon its surface, at a particular angle. The crude metal, thus acted upon by the oxygen of the air, is in about three hours sufficiently decarbonised and refined, to render it suitable for the puddling process; it is therefore run out of the 'finery' and formed into a large flat plate, which is of an extremely hard and brittle character, and presents physically no approach whatever to the malleable state. The hard and brittle mass, thus formed, is easily broken by the hammer into pieces of a size suitable for the puddling furnace, to which it is conveyed, in order to be more completely decarbonised and rendered malleable.

Iron on the verge of fusion loses its power of cohesion, and readily crumbles down into a coarse powder. This property is common to pig and to refined iron, and advantage is taken of it in the puddling process. The workman watches the temperature and appearance of the metal, and seizing the proper moment, divides the masses of refined iron into small fragments, which he spreads about the furnace, and finally breaks it down into a kind of coarse sand. The metal, in this divided state, exposes a large extent of surface to the refining action of the fluid cinder, as well as to the volume of air constantly passing through the furnace. By increasing the heat, the granulated mass swells up and emits numerous jets of blue flame. At this point the puddler diligently stirs and works the metal, until the flame appears of a whiter colour, and the metal becomes clotty and tenacious, or as the workmen term it, 'comes to nature;' after which, the iron is gathered into balls, and is then removed, as quickly as possible, to the squeezer, where much of the fluid scoriæ and other mechanically mixed impurities are driven out, leaving a mass or billet of iron, composed of thousands of separate fragments of metal, the entire surface of every one of which is more or less coated with dry oxide, or fluid silicate of the oxide of iron. The great pressure exerted by the squeezer suffices to so far remove the fluid coating of contiguous particles as to bring their surfaces into actual contact, and consequently to effect an union at such parts.

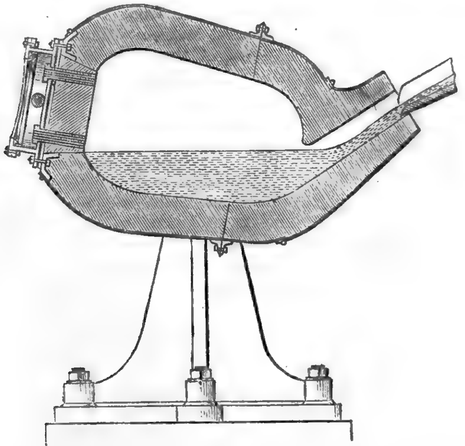
In the puddling process, the granules of metal gradually pass from the state of brittle finery-iron to steel, and passing that point, through every gradation of hard, medium, and soft steel, eventually arrive at the softest stage of decarbonised iron. The time occupied in these changes varies with the size of the granules, their temperature, and the extent to which each is exposed to the action of the air passing through the furnace.

It need not be a matter of surprise that when it was first proposed, by Mr. Bessemer, to convert crude pig-iron into malleable iron, while in a fluid state, and to retain the fluidity of the metal for a sufficient time to admit of its being cast into moulds, without the employment of any fuel in the process, that his proposition was almost generally looked upon as a mere day-dream, which the practical man felt bound to disbelieve.

Chemical investigation soon pointed out the real source of the difficulties which surrounded the Bessemer process. It was found that, although the metal could be wholly decarbonised, and the silicium be removed, the quantity of sulphur and phosphorus was but little affected. As different samples were carefully analysed, it was ascertained that the red shortness was always produced by sulphur, when present to the extent of one-tenth per cent., and that cold shortness resulted from the presence of a like quantity of phosphorus. It therefore became necessary to remove these substances. Steam and pure hydrogen gas were tried, with more or less success, in the removal of sulphur, and various fluxes, composed chiefly of silicates of the oxides of iron and manganese, were brought in contact with the fluid metal during the process, and the quantity of phosphorus was thereby reduced.

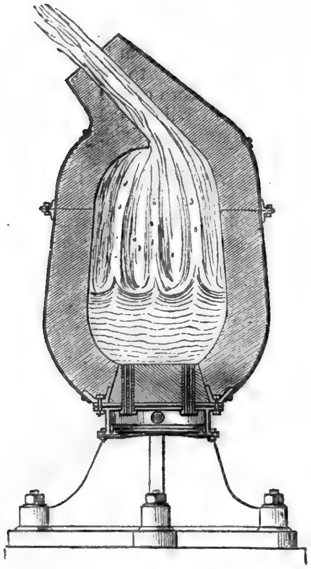
In manufacturing tool-steel of the highest quality, it was found preferable, for several reasons, to use the best Swedish pig-iron, and when converted into steel, by the Bessemer process, to pour the fluid steel into water, and afterwards to remelt the shotted metal in a crucible, as is at present practised with blister steel, by which system the small ingots required for this particular article are more perfectly and more readily made. The production of first-class steel by the new process, although a mater of deep interest in one of the smaller branches of the iron trade, still left untouched that great source of this country's prosperity, the manufacture of malleable iron. It was, therefore, impossible to rest content without accomplishing this, the original object of the invention. On examining into the stores of mineral wealth so abundant in these islands, it was found that iron ore of the requisite purity existed as red hæmatite in vast beds. There are also extensive veins of spathose ore or carbonate of iron, and magnetic ores.

1908



'The form of converting vessel which has been found most convenient, and by which superior specimens are produced, is shown in *fig.* 1908. The vessel is mounted on axes, at or near its centre of gravity. It is constructed of boiler-plates, and is lined either with fire-brick, road-drift, or 'ganister' (a local name in Sheffield for a peculiar kind of powdered stone), which resists the heat better than any other material yet tried, and has also the advantage of cheapness. The vessel having been heated, is brought into the position shown in *fig.* 1908, so that it may receive its charge of melted metal, without either of the tuyères being below the surface. No action can, therefore, take place until the vessel is made to assume the position shown in *fig.* 1909. The process is thus in an instant brought into full activity, and small though powerful jets of air spring upward through the fluid mass. The air expanding in volume, divides itself into globules, or bursts violently upwards, carrying with it some hundredweights of fluid metal, which again falls into the boiling mass below. Every part of the apparatus trembles under the violent agitation thus produced, a roaring flame rushes from the mouth of the vessel, and as the process advances, it changes its violet colour to orange, and finally to a voluminous pure white flame. The sparks, which at first were large, like those of ordinary foundry iron, change to small hissing points, and these gradually give way to soft floating specks of bluish light, as the state of malleable iron is approached. There is no eruption of cinder as in the early experiments, although it is formed during the process; the improved shape of the converter causes it to be retained, and it not only acts beneficially on the metal, but it helps to confine the heat, which during the process, has rapidly risen from the comparatively low temperature of melted pig-iron, to one vastly greater than the highest known welding heats, by which malleable iron only becomes sufficiently soft to be shaped by the blows of the hammer; but here it becomes perfectly fluid, and even rises so much above the melting-point as to admit of its being poured from the converter into a founder's ladle, and from thence to be transferred to several successive moulds. The thin shell, or skull of the ladle, shows the extreme fluidity of the metal, and also how little of it is solidified in the ladle during the time of casting.

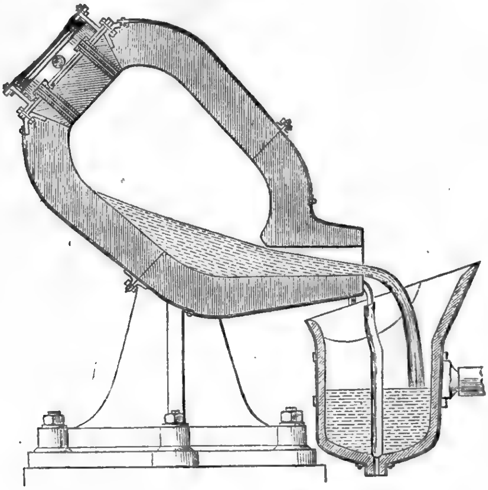
1909



'The oxygen of the air appears, in this process, first to oxidize the silicium, producing silicic acid, and next to seize the carbon which is eliminated, while the silicic acid, uniting with the oxide of iron, obtained by the combustion of a small quantity of metallic iron, thus produces a fluid silicate of the oxide of iron, or 'cinder,' which is retained in the vessel, and assists in the purification of the metal. The increase of temperature which the metal undergoes, and which seems so disproportionate to the quantity of carbon and iron consumed, is doubtless owing to the favourable circumstances under which combustion takes place. There is no intercepting material to absorb the heat generated, and to prevent its being taken up by the metal; for heat is evolved at thousands of points, distributed throughout the fluid, and when the metal boils, the whole mass rises far above its natural level, forming a sort of spongy froth, with an intensely vivid combustion going on in every one of its numberless ever-changing cavities. Thus, by the mere action of the blast, a temperature is obtained in the largest masses of metal, in ten or twelve minutes, that whole days of exposure in the most powerful furnaces would fail to produce.'

The changes in the colour and volume of the flame, and the kind of sparks thrown off, afford easy modes of judging of the state of the metal, since these are given off exteriorly, and are not interfered with by the flame of the fuel, as in the puddling furnace. The sound which the metal produces in the suspended vessel affords also a good indication to the workman. Indeed, few processes appeal so strongly to the external senses. All mere judgment on this point has, however, been rendered unnecessary, by the more certain indications, of an apparatus, which registers on a dial the exact number of cubic feet of air passed through the metal, whereby the precise degree of hardness of the steel is regulated at pleasure; its quality, in all cases, being dependent on the quantity of air passed through it; other circumstances being alike. When, therefore, the desired quantity of air has passed through the metal, the vessel is turned on its axis, and the fluid steel is poured out, as shown at *fig.* 1910.

1910



It is then received in the casting-ladle, which is attached to the arm of a hydraulic crane so as to be brought readily over the moulds. The ladle is provided with a fire-clay plug at the bottom, the raising of which, by means of a suitable lever, allows the fluid steel to descend in a clear, vertical stream into the moulds. As soon as the first mould is filled, the plug valve is depressed, and the metal is prevented from flowing until the casting-ladle is moved over the next mould, when, by raising the plug, the second mould is filled in a similar manner; and so on, until all the moulds are filled. After the discharge of the metal from the vessel, the process should be repeated without delay, since the temperature of the interior of the vessel is greater after the first charge than it was before, and consequently it is in a better condition for the process. The vessel may be moved on its axis by suitable gearing, but it is considered preferable to use hydrostatic pressure to effect every movement of the crane and of the vessel; so that when operating on from 5 to 10 tons at a single charge, the director of the process can, from a distant point, and with his own hands, effect every movement required, by merely working the handles which turn on, or off, the pressure of the water. He has also charge of the blast-cock, whilst the dial for registering the number of cubic feet of air is before him; and thus, by the control of one responsible man, charges of several tons of crude cast iron may be converted into malleable iron, or into steel, in a few minutes, and be cast into ingots of any desired form and weight, suitable for large shafts, or for rolling into rails, merchant bars, or plates.

The slags of the Bessemer process vary considerably in composition from those of the puddling furnace, being much more acid and approximate to the pyroxene formula. At Hörde, in Westphalia, a crystallised slag has been obtained which yielded, by analysis: silica, 44·73; protoxide of iron, 20·59; protoxide of manganese, 32·74; lime, 1·53; magnesia, 0·17 = 99·76.

Oxygen-ratio of silica to bases = 23·85 : 12·43.

Specific gravity, 3·08.

The crystals were found to be of the regular augite form, the angles being intermediate between those of the natural minerals, Pajsbergite and Babingtonite, as is also their composition.

The enormously high temperature developed by the action of cold air on molten cast iron in the Bessemer process is obviously due to the extreme rapidity with which the operation takes place, and the advantageous form of the converter for concentrating the heat developed. For, although the reactions and consequently the heat produced are in no way different from those of other finery processes, whether in the open fire or reverberatory furnace—carbon, silicon, manganese, and some iron being burnt in either case, with the production of carbonic oxide, silicates of protoxide of iron and manganese, and malleable iron—we have, in the blowing of a charge weighing five tons an amount of work done in about two and a half to three days in its performance in the puddling furnace. It has been pointed out by Jordan, that the principal part of the heat developed in the process is due to the combustion of silicon, which when oxidised to silicic acid, combines with protoxide of iron, and other bases, and remains in the bath in the form of slag; while in the case of carbon, a considerable portion of the heat is expended in volatilising the carbonic oxide produced, which escapes at the temperature of the melted metal, and burns to waste at the mouth of the converter. If the calorific power of silicon be assumed to be the same as that of carbon, the amount of heat produced by the combustion of one kilogramme of silicon to silicic acid will be 8,000 units,[1] when burnt in pure oxygen, or 6,382 in air; the difference between the two quantities corresponding to the amount required to heat up the inert nitrogen. Under the latter condition, one kilogramme of carbon will produce only 475 effective units, being the difference between 2,473 units theoretically developed and 1,998 units carried off by the gaseous products carbonic oxide and nitrogen, supposing them to escape at a temperature of 1400°. The use of steam instead of air as an oxidising agent, is, in the case of the combustion of iron or carbon, always disadvantageous on account of the great amount of heat required to free the oxygen from its combination with hydrogen, which is not reproduced to the same extent in the subsequent formation of carbonic oxide or protoxide of iron. With silicon, however, the conditions are somewhat different, as there is a small sensible gain. This will explain the reason why the use of steam in the refinery is only recommended for a few minutes at the commencement of the operation, that is, as long as free silicon remains in the pig-iron under treatment.

By applying the quantities given above to the calculation of the amount of heat developed in the blowing in one ton of Bessemer pig-iron of the ordinary quality produced in the south of France (which has the following composition per ton of 1,000 kilogrammes: carbon, 42·50; silicon, 20·00; iron and manganese, 937·50 = 1000·00), Jordan arrives at the following results:—

	Kilogrammes		Units of heat
The combustion of	20	of silicon produces . . .	127,648
,,	42·5	of carbon produces . . .	20,176
,,	87·5	of iron and manganese produces	66,237
		Or a total of .	214,061

If we take the specific heat of molten malleable iron at 0·16, the amount of heat developed will be sufficient to raise the temperature of the metal, which is supposed to be completely decarbonised, about 1350° above that of the cast iron when run into the converter.

The great heating power of silicon is, therefore, to be regarded as the reason for the use of dark-grey iron in the Bessemer process; under ordinary circumstances, about 2 or 2·5 per cent. silicon being considered as essential. Jordan states that in the steel works in the south of France the process could only be carried out by running the cast iron directly from the blast-furnace into the converter. The amount of silicon as a heat-producer in the Bessemer process may be, to some extent, taken by manganese; as is the case in Styria, where the cast iron used is smelted from the spathic ores. It is, however, less advantageous, because the deficiency in silica, which is required to flux the protoxide of manganese formed, can only be supplied by the destruction of the siliceous lining of the converter. The corrosive action of manganese on the hearths of blast-furnaces where spathic ores are smelted has already been noticed.

Although silicon is an essential component of good Bessemer pig-iron, it is of importance that the amount per cent. should be somewhere about the same as, or not very much more than that of the carbon. An excess of the former element, works prejudicially in two ways: first, it gives rise to an increased waste of iron in the slag; and secondly, it cannot be completely removed before the whole of the carbon is burnt away, so that it may happen in the blowing of such metal, that, although the process is apparently complete, as determined by the usual indication of the cessation of the flame from the converter, sufficient silicon is retained in the decarbonised metal to render the finished steel brittle and useless. Snelus gives the following analyses in illustration of this point:—

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[1] This is in excess of the real amount, which has recently been determined to be 7,000. Jordan's original figures are however preserved, as the quantities are only given as approximations, for the purpose of illustrating the theory of the process, and not as absolute numerical determinations.

	I.	II.	III.	IV.
Carbon	0·445	0·515	0·550	0·490
Silicon	0·814	0·270	0·640	0·009
Sulphur	...	...	0·067	0·033
Phosphorus	...	...	0·038	0·036
Manganese	...	...	0·554	0·576
Copper	...	...	0·031	0·025

Analyses I. II. and III. are examples of under-blown and brittle steel, rich in silicon; IV. is the ordinary composition of good Bessemer rail-steel made at Dowlais.

The following series of analyses, by the same chemist, of metal taken at different stages of the blow, show very distinctly the gradual removal of the carbon along with the silicon:—

	I.	II.	III.	IV.	V.	VI.
Carbon, graphitic	2·070	...	...	...	...	...
„ combined	1·200	2·170	1·550	0·097	0·566	0·519
Silicon	1·952	0·795	0·635	0·020	0·030	0·030
Sulphur	0·014	trace	trace	trace	trace	trace
Phosphorus	0·048	0·051	0·064	0·067	0·055	0·053
Manganese	0·086	trace	trace	trace	0·309	0·309
Copper	...	...	...	...	0·039	0·039
Ratio of carbon to silicon	1·6 : 1	2·7 : 1	2·4 : 1	4·8 : 1	19 : 1	17 : 1

I., melted charge of pig; II., metal at end of first stage, 6 minutes from start; III., metal after blowing 9 minutes; IV., over-blown metal, 13 minutes from start, before adding spiegeleisen; V., steel from ingot; VI., steel from finished rail.

The difference in the amount of copper, which is much larger in the Styrian steel than in that from Dowlais, is to be attributed to the fact that the pig-iron used in the former is entirely smelted from spathic ore, while in the latter only the spiegeleisen is due to that source. Copper pyrites, in small quantity, is almost invariably present in spathic carbonates, and however carefully they may be washed and weathered, some copper, as a general rule, is reduced and passes into the iron in the blast-furnace.

The progress of the conversion of the charge can be controlled to some extent by observing the spectrum given by the flame with the spectroscope; and more particularly the moment of complete decarbonisation may be determined with considerable accuracy, especially if the flame be bright and free from smoke. The spectrum produced when the combustion is most active is characterised by groups of numerous lines in the yellow and green portions, that of sodium being the most prominent and the first to appear among the former. There is also a well-defined group of lines in the blue field, and under the most favorable conditions the violet and red lines of potassium and lithium, together with an extra violet line accompanying the former are seen. For this, however, an instrument of great defining power and an extremely bright flame are essential. When the metal is completely decarbonised, the yellow and green lines disappear, but the sodium is persistent, sometimes even after the tipping of the converter. On the addition of the spiegeleisen, the whole of the lines reappear with great brilliancy. When there is much manganese in the cast iron employed, as is the case in Styria, the use of the spectroscope is difficult, owing to the brown smoky character of the flame.

At Seraing, it has been found that the disappearance of the dark absorption-bands, which alternate with the bright lines, can be more readily determined than the latter, which often reappear after their apparent extinction, and is therefore to be preferred as admitting of much closer and easier observation.

The exact chemical character of the spectrum of the Bessemer flame has not as yet been made out, although it has been the cause of considerable controversy, there being two different opinions as to its origin. One of these supposes the lines to be due to carbonic oxide, and their cessation to the complete combustion of the carbon; while the other considers that they are mainly produced by manganese, and that their sudden disappearance may be accounted for by the diminution in the amount of the metal volatilised until the quantity present in the flame is reduced below that necessary to produce them, it having been found that for the detection of manganese by the spectroscope much larger quantities must be employed than are sufficient to produce the ordinary reaction with soda on platinum-foil before the blowpipe.

Another indication of the progress of the operation is that afforded by the character of the slag. This has been employed in Austria and Sweden. An iron rod is inserted into the converter, and when brought out a portion of the slag adheres to the point. So long as any carbon remains unconsumed a peculiar brownish tint is observed; but as soon as the point of total decarbonisation is reached, the slag assumes a dead black colour, with a peculiar metallic lustre, characteristic of the presence of protoxide of iron, in considerable quantity. This test is said to be capable of great precision in the hands of experienced workmen.

The largest series of Bessemer converters hitherto erected are those at Barrow-in-Furness. They are arranged in two groups, of which one has four converters, taking 7½-ton charges, and the other a similar number of a smaller size, holding 6 tons each. The former are 9½ feet in greatest diameter, and 14¾ feet high. In all cases the proportion occupied by the melted metal is very small as compared with the entire capacity of the converter, a large empty space being required in order to prevent the ejection of the fluid contents when the boiling is at the highest point.

In Sheffield the loss of weight on the pig-iron employed is about 15 per cent. in addition to 7½ per cent. in the reverberatory melting furnace, or 22½ per cent. in all. With 3-ton converters the lining has to be renewed after blowing 250 tons; but the tuyères wear out much quicker, and must be replaced after making 10 tons, that is, after every third or fourth operation.

The number of charges made daily is not more than four for each converter, as although the actual blowing does not require more than fifteen or twenty minutes, a considerable time is required for the accessory operations of melting the pig-iron, the solidification and removal of the castings, and the arrangements of the moulds.

The ingots, when drawn from the moulds, like those obtained from steel melted in crucibles, are always more or less unsound, and require to be compacted by hammering. For this purpose, they are raised to a bright red heat in a reheating furnace, care being taken to keep the hearth filled with smoking flame in order to prevent the carbon from burning away. They are then hammered, and at a second heat swaged down to the form of the first groove of the rolling mill, when intended for bars or rails. The length of the ingot is extended from 4½ to 8 feet under the hammer. In rolling rails two heats are required in addition. Spherical shots are cast a little larger than the size required, and afterwards reduced to the proper figure and dimensions by a steam-hammer with hemispherical swages.

Most metals, it must be observed, on losing their fluidity, lose for the moment their power of cohesion. Malleable iron, however, passes from the fluid into the pasty state, in which it possesses the property of welding, which forms so well-known and remarkable a peculiarity of that metal. Taking advantage of this fact, Mr. Bessemer tried an experiment on manufacturing iron, direct from the fluid metal, into endless sheets, in a manner analogous to that by which paper is now made of any length; this has not, however, been much used.

Considerable discussion has arisen respecting the introduction of manganese in the Bessemer steel, both as to its value in producing a superior metal, and as to the discovery of its value in the process. These questions were satisfactorily answered in a communication read before the British Association at Birmingham in 1865, to which those who are interested in the process are referred.

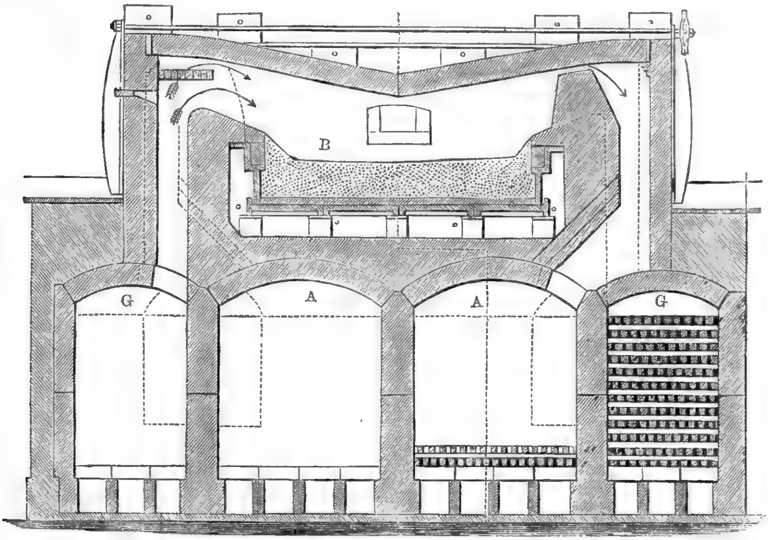
Siemens-Martin Process.—The production of cast steel in the reverberatory furnace, by dissolving malleable scrap in molten cast iron according to the method proposed by Heath, Price, and Nicholson, and others, has of late been brought to a considerable degree of perfection by the use of the regenerative gas-furnace, which gives an intense heat without requiring an oxidising or cutting draught; as is the case with ordinary stack-draught furnaces. The process was first carried out on a working scale by Martin of Sireuil, near Paris, who has given his name jointly with that of Siemens to the process. The furnace is represented in longitudinal and transverse section in *figs.* 1911 and 1912. The regenerators A A and G G are placed below the bed in the usual manner, the former being employed for heating air and the latter for gas. The bed B is made of finely-ground quartz sand, consolidated by pressure, with strong heating, and is supported on cast-iron plates, which are kept cool by a circulation of air. The surface of the bed is flat, with a slight inclination towards the top hole, which is placed below the middle working-door, on the front of the furnace. The ladle, which has a similar arrangement for running out the steel through a hole in the bottom, to that employed in the Bessemer process, is mounted upon wheels, and travels upon a railway, the ingot-moulds being arranged in a straight line in the pit below.

According to the size of the furnace, the charge may be from 35 cwts. to 5 tons. The materials used are good pig-iron, such as that employed for Bessemer steel-making, wrought iron in the form of bars, malleable scrap, or Bessemer steel cross-ends and waste, and spiegeleisen. The pig-iron is first melted, and the malleable iron or steel is added in small quantities at a time; care being taken to raise it to a white heat by exposure to the stream of gas on the bridges before immersing it in the bath of molten cast iron.

The reversal of the gas- and air-valves takes place every 20 minutes. As soon as the entire charge is dissolved, a sample of the metal is taken out in a small wrought-iron ladle, and after casting, is cooled in water and broken.

The heat is continued with an oxidising flame until the assay-sample, although suddenly cooled, gives a perfectly soft and tough metal, indicating the point of total decarburisation. When the spiegeleisen is added, care should be taken to charge it through the hole nearest to the bridge, which at the time is on the flue side of the furnace. When it is melted, which usually takes about 20 minutes time, the charge is stirred, in order to mix the contents as uniformly as possible: an operation which must be done quickly, in order to prevent loss of manganese in the slag. The contents of the furnace are then run into the ladle and cast into ingots in the usual way, the same precautions being observed as in the Bessemer process. Usually three charges are made in 24 hours. The yield per charge of 35 cwts. is from 32 to 33 cwts. of ingots, the ordinary loss being 8½ per cent., or in the most favourable case, about 6 per cent. The furnace must be let down for repairs at intervals of six weeks at the longest.

1911



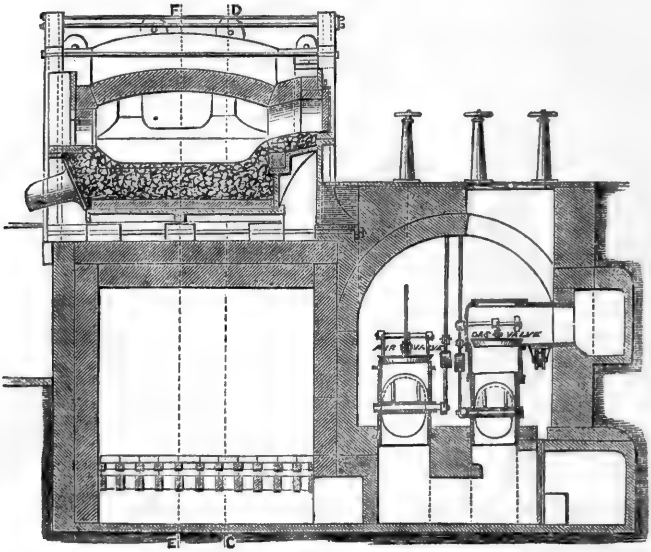
This process is of great advantage for the working-up of the waste of Bessemer steel-works, which cannot safely be added to the charge in the converter; a plan which has been tried, but not with success. Puddled bars, made specially, cut into proper lengths, and good scrap, such as that obtained in the neighbouring tin-plate forges, are the principal forms of malleable iron used in South Wales.

Another modification of the Siemens process consists in the use of finely-divided iron in the spongy state produced by the reduction of a pure red or brown hæmatite by a current of carbonic oxide at a red heat, instead of bars or other manufactured forms of malleable iron. In the newest arrangement adopted for this purpose, the finely-divided spongy iron produced in upright retorts is made to pass into a gas-furnace with an enclosed bed, where it is consolidated by immersion into a melted magnetic oxide of iron, produced by the partial reduction of hæmatite, sufficient lime being incorporated with the mass to flux the silica of the ore. These agglomerated masses are then treated in the bath of pig-iron, producing steel directly by the oxidising action of the magnetic oxide in the carbon in the melted metal. The above process has since been abandoned in favour of the rotatory furnace described under the article **Iron**.

In a lecture delivered by Dr. C. Wm. Siemens before the Chemical Society, he thus described his process of producing cast steel upon the open hearth of a regenerative furnace. Two processes are employed at the Landore works: the Siemens-Martin process, which consists, as already stated, in dissolving scrap-metal or steel in a bath of pig-metal, to which spiegeleisen is finally added; and the ore-reducing process, in which pig-metal and ore in a more or less reduced condition is employed.

The process chiefly employed at the Landore works consists of introducing on the bed of an intensely-heated regenerative gas-furnace, as shown in *figs.* 1911 and 1912, about 6 tons of pig-metal, which may be No. 3 or 4 hæmatite pig. When a fluid-bath has been formed, oxide of iron, which should by preference have been smelted beforehand with such proportions of lime or other fluxing materials as to form with the silica in the ore and in the pig-metal, a convenient slag, is added; or natural ores may be used in their raw condition if they contain lime and manganese, as for example, the African Mokta ore. When about 30 cwts. of this ore have been dissolved (with ebullition,) in the metallic bath, it is found that a sample taken from it contains only about 1 per cent. of carbon: a point which can easily be detected by the eye of the workman by a peculiar bright appearance of the sample when chilled in water and broken by the hammer.

1912



Considerable difficulty was experienced to find a material to resist the excessive heats necessary for carrying out this process: ordinary Dinas bricks, which are considered the most refractory material in general use, would be rapidly melted; but a brick specially prepared by crushing pure quartz-rock, and mixing it with no more than 2 per cent. of quick-lime to give cohesion, answers well. The hearth of the furnace is made of white sand with a small admixture of more fusible fine sand, which mixture sets exceedingly hard at a steel melting-heat, and possesses the advantage of combining into a solid mass with fresh materials introduced between the charges to make up for wear and tear. The hearth and the furnace-roof, if of the materials just specified, are very little attacked when the Siemens-Martin process is used, although the heat must be sufficient to maintain wrought iron containing only a trace of carbon in a perfectly fluid condition. If pig-metal and ore (fused together with the necessary amount of flux) is used, the furnace also stands well, but the use of raw ore entails the disadvantage of a more rapid destruction of the furnace; even magnetic oxide of the purest description necessitates the addition of raw lime for the formation of a fusible slag, and the dust arising from the lime and sand through the decrepitation of the ore, causes the silica-bricks to melt away rapidly, so that, after perhaps two months' usage, the 9-inch arch of the furnace is reduced to the thickness of from 1 to 2 inches. It is evident that silica is, chemically speaking, an objectionable material to be used in the construction of these furnaces, because it prevents the formation of basic slags, and that a furnace constructed of pure alumina or lime would be preferable. M. Le Chatelier suggested, some years ago, the use of *Bauxite* (from Beaux in France, where it was first discovered), a mineral consisting chiefly of alumina, for making the furnace-beds, but Dr. Siemens was not able to succeed with this, owing to the great contraction of the mass when intensely heated, and non-cohesion with the same material introduced for the purpose of repair. In attempting to construct the sides and roof of the furnace of Bauxite bricks, these were not found to be equal in heat-resisting power to silica-bricks, which latter are indeed unobjectionable, except when raw ore and limestone are used. See BAUXITE.

STEEL, HARDENING OF. Steel may be hardened by plunging it into cold water. Prussiate of potash and other salts are used for producing especial degrees of hardness. See TEMPERING OF STEEL.

STEMPLES. A *mining term.* Strong pieces of timber, driven betwixt the sides of a vein, at short distances apart, to support the walls.

STEREOCHROME. A name given to a process of stereotyping, the printing of which is effected in colours. It is a term also used for the art of painting, with silica fluids for mixing the colours.

STEREOSCOPE (from Gr. *στερεός*, *stereos*, 'solid,' and *σκοπεῖν*, *skopein*, 'to see'). An instrument invented by Professor Wheatstone, and modified by Sir David Brewster, by means of which two images of the same object, depicted on paper,—as those images would be depicted upon the retina of each eye—are resolved into an apparent solid of three dimensions. The reflecting stereoscope of Professor Wheatstone was constructed by means of two mirrors, set at right angles to each other, so that while the right eye observed a reflected image of a picture placed on the right-hand side of the instrument, the left eye saw a reflected image of that on the left, and, as a result, saw—not two plane pictures, but one solid image. The refracting stereoscope, which is generally used, consists of two semi-lenses. This is a lens which is divided in the middle, and the two halves, with the edges towards each other, placed in a frame, at a distance from each other corresponding with the distances of the eyes apart. For the best result, two pictures are obtained by photography, as nearly as possible of the same character as the pictures impressed respectively upon the retina of each eye. See Hunt's 'Manual of Photography.'

STEREOTYPE PRINTING signifies printing by fixed types or by a cast typographic plate. This plate was formerly always, and is still sometimes, made as follows:—The form, composed in ordinary types, and containing, one, two, three, or more pages, inversely as the size of a book, being laid flat upon a slab, with the letters looking upwards, the faces of the types are brushed over with oil, or, preferably, with plumbago (black lead). A heavy brass rectangular frame of three sides, with bevelled borders adapted exactly to the size of the pages, is then laid down upon the chase,[1] to circumscribe three sides of its typography; but the fourth side, which is one end of the rectangle, is formed by placing near the types, and over the hollows of the chase, a single brass bar, having the same inwards-sloping bevel as the other three sides. The complete frame resembles that of a picture, and serves to define the area and thickness of the cast, which is made by pouring the pap of Paris-plaster into its interior space up to a given line on its edges. The plaster-mould, which soon sets, or becomes concrete, is lifted gently off the types, and immediately placed upright on its edge in one of the cells of a sheet-iron rack mounted within the cast-iron oven. The moulds are here exposed to air heated to fully 400° Fahr., and become perfectly dry in the course of two hours. As they are now friable and porous, they require to be delicately handled. Each mould, containing generally two pages octavo, is laid, with the impression downwards, upon a flat cast-iron plate, called the floating-plate; this plate being itself laid on the bottom of the dipping-pan, which is a cast-iron square tray, with its upright edges sloping outwards. A cast-iron lid is applied to the dipping-pan and secured in its place by a screw. The pan having been heated to 400° in a cell of the oven, under the mould-rack, previous to receiving the hot mould, is ready to be plunged into the bath of melted alloy contained in an iron pot placed over a furnace, and it is dipped with a slight deviation from the horizontal plane, in order to facilitate the escape of the air. As there is a minute space between the back or top surface of the mould and the lid of the dipping-pan, the liquid metal on entering into the pan through the orifices in its corners, floats up the plaster along with the iron plate on which it had been laid, thence called the floating-plate, whereby it flows freely into every line of the mould, through notches cut in its edge, and forms a layer or lamina upon its face, of a thickness corresponding to the depth of the border. Only a thin metal film is left upon the back of the mould. The dipping-pan is suspended, plunged, and removed, by means of a powerful crane, susceptible of vertical and horizontal motions in all directions. When lifted out of the bath, it is set in a water-cistern, upon bearers so placed as to allow its bottom only to touch the surface. Thus the metal first concretes below, while by remaining fluid above, it continues to impart hydrostatic pressure during the shrinkage attendant on refrigeration. As it thus progressively contracts in volume, more metal is fed into the corners of the pan, in order to keep up the pressure upon the mould, and to secure a perfect impression, as well as a solid cast.

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[1] Chase (*chassis*, Fr., 'frame'), and quoin (*coin*, Fr., 'wedge'), are terms which show that the art of printing is indebted to our French neighbours for many of its improvements.

The whole process is greatly improved by the employment of a prepared bibulous paper, instead of the plaster-of-Paris. The paper employed was originally of French manufacture, but is now made in England. Four sheets of tissue and one sheet of brown paper being pasted together, it forms one sheet. The form of type being ready, a sheet of this prepared paper is placed upon it, and it is then beaten into the face of the type by hard hand-brushes. It is then filled in the blank parts with paste, when the whole is then covered by a thicker sheet of paper, and it is then passed under a heated press for about two minutes to dry. On removing the paper it is found to have received a most perfect impression of the type. This impressed paper mould is then placed in an iron box, which is fixed in a nearly vertical position, and the heavy cover being carefully closed, there only remains between it and the mould exactly the space which is necessary to ensure a proper thickness to the type-metal. All being prepared, the melted metal is poured into the mould. It flows, of course at once to the bottom of the mould, and as the liquid is rapidly supplied, the whole is filled, and, as in the case already given, some pressure is obtained by the head of metal above the paper-mould. The mass of metal (iron) forming the casting box, in comparison with the thin plate of type-metal, ensures a rapid chilling of the latter, so that the plate can be removed in a very short time. The impression thus obtained is exceedingly perfect; and the whole process is one of great simplicity and exactness, and is capable of being executed with great rapidity.

'The Times' and other daily newspapers are regularly printed from stereotype-plates; but most of the machines for taking the matrices, were invented by Mr. Sweet, at 'The Times' office, and save one half of the time used by beating the form with brushes, each plate being cast and placed on the machine in about a quarter of an hour.

The advantages of a solid block over a form of loose type will be sufficiently obvious to all; and, but for the security which is afforded by the use of the solid plate, there would be great risk in driving the printing machinery at such high rates of speed as are employed in 'The Times' office and other offices, where they require to throw off a very large impression within a very limited time. See PRINTING and PRINTING MACHINERY.

STILL. See DISTILLATION.

STIPPLE ENGRAVING is a process which was practised by Bartolozzi, Ryland, and others, in imitation of chalk-drawings of the human figure. Stipple is performed with the graver, which is so managed as to produce the tints by small dots, rather than by lines, as in the ordinary method. It is very soft in its effect, but inferior to the more legitimate mode of engraving. See ENGRAVING.

STOCKING MANUFACTURE. See HOSIERY.

STONE is earthy matter, condensed into so hard a state as to yield only to the blows of a hammer, and therefore well adapted to the purposes of building. Such was the care of the ancients to provide strong and durable materials for their public edifices, that but for the desolating hands of modern barbarians in peace and in war, most of the temples and other public monuments of Greece and of Rome would have remained perfect at the present day, uninjured by the elements during 2,000 years. The contrast, in this respect, of the works of modern architects, especially in Great Britain, is very humiliating to those who boast so loudly of social advancement; for there is scarcely a public building of recent date which will be in existence one thousand years hence. Many of the most splendid works of modern architecture are hastening to decay, in what may be justly called the very infancy of their existence. This is remarkably the case with the bridges of Westminster and Blackfriars; the foundations of which began to perish most visibly in the very lifetime of their constructors.

Stones for building, it is stated, may be proved as to their power of resisting the action of frost, by the method, first practised by M. Brard, and afterwards by MM. Vicat, Billaudel, and Coarad, engineers of the bridges and highways in France. The operation of water in congealing within the pores of a stone may be imitated by the action of a salt, which can increase in bulk by a cause easily produced; such as efflorescence or crystallisation, for example. Sulphate of soda, or Glauber's salt, answers the purpose perfectly, and it is applied as follows:—

Average samples of the stones in their sound state, free from shakes, should be sawed into pieces 2 or 3 inches cube, and numbered with China-ink or a graving tool. A large quantity of Glauber's salt should be dissolved in hot water, and the solution should be left to cool. The clear saturated solution being heated to the boiling point in a saucepan, the several pieces of stone are to be suspended by a thread in the liquid for exactly one half-hour. They are then removed and hung up each by itself over a vessel containing some of the above cold saturated solution. In the course of 24 hours, if the air be not very damp or cold, a white efflorescence will appear upon the stones. Each piece must be then immersed in the liquor in the subjacent vessel, so as to cause the crystals to disappear, be once more hung up, and dipped again whenever the dry efflorescence forms. The temperature of the apartment should be kept as uniform as possible during the progress of the trials. According to their tendency to exfoliate by frost, the several stones will show, even in the course of the first day, alterations on the edges and angles of the cubes; and in five days after efflorescence begins, the results will be manifest, and may be estimated by the weight of disintegrated fragments, compared to the known weight of the piece in its original state, both taken equally dry. In opposition to this, Mr. C. H. Smith, one of the commissioners for selecting the stone for the Houses of Parliament, states—'Such treatment, compared with that of nature, will be found to vary materially, both in detail and result. If Glauber's salt expands in changing from a fluid to a crystalline state, it is so little as to be inappreciable; whereas water increases considerably in bulk while freezing.' Many experiments selected from the Report on Stone for the New Houses of Parliament (March 1839), show that in M. Brard's treatment the effect is in most instances opposite to that of the action of the weather on stones which have been exposed to its influence many years. Some of the specimens well known to decay rapidly in a building disintegrated least of all by Brard's process; others of the most durable quality disintegrated more than all the rest, under similar treatment; consequently Brard's method of testing is not to be depended upon, and is liable to lead to erroneous conclusions.

The most important building-stones of the United Kingdom are the following:—

Granites—produced chiefly in Cornwall, Devonshire, Leicestershire, Aberdeenshire, and in Wicklow and Carlow.

Porphyries, Syenites, Elvans—obtained from Cornwall, Devonshire, Leicestershire, and many parts of Scotland and Ireland.

Sandstones—the chief quarries of which are in Yorkshire, Derbyshire, Shropshire, Surrey, &c., and in several of the Scottish counties. The Darley Dale, Craigleith, and other celebrated stones, belong to this class.

Millstone Grit is found largely in Derbyshire, in Yorkshire, and indeed in most of the coal-producing districts.

Dolomites, or Magnesian Limestones—Yorkshire, Durham, Northumberland, Derbyshire, and Nottinghamshire, produce these stones abundantly.

Oolites. The Bath Stone and Portland Stone are well-known examples of this stone; the stone from the quarries of Ancaster and of Ketton are also fine specimens of the class.

Limestones. These are very varied; the Purbeck marble, the Derbyshire marbles, the Lias beds, the Devonian Limestone, and the well-known Mountain Limestone being examples.

Slates. These are obtained in very great abundance in North Wales, in Devonshire, and in Cornwall; in some parts of Scotland and of Ireland.

Such are the principal varieties, although many others exist which are exceedingly useful. Most of the above will be found described under their respective heads.

STONE, ARTIFICIAL, for statuary and other decorations of architecture, has been made for several years with singular success at Berlin, by Mr. Feilner. His materials are nearly the same with those of English pottery; and the plastic mass is fashioned either in moulds or by hand, being in fact a Terra-Cotta, which see. His kilns were peculiar in form, and economical in fuel, but they were in but few respects different from the pottery-kilns already described. See Kiln.

Many ingenious arrangements have been made for the construction of artificial stone. We might, of course, group under this head many varieties of clay-wares and cements.

Amongst all the numerous plans which have been devised, few of them have altogether succeeded; they have either proved too expensive in the manufacture, or they have not endured the test of time.

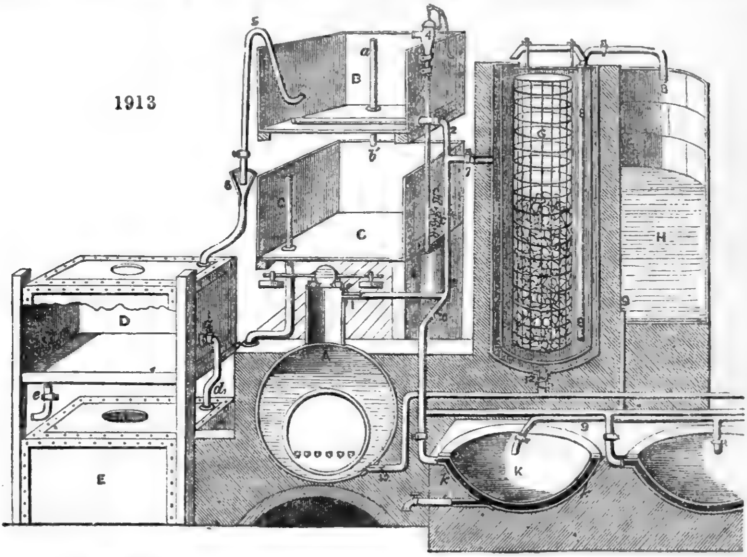
Mr. Buckwell proposed the following:—Taking fragments of stone sufficiently large to go freely into his mould, he fills up the interstices with stones of various sizes, and then pours in a mixture of chalk and Thames mud or Mersey mud burnt together. This cement being poured into the mould, the whole is rammed together by falling hammers, and as the mould is perforated, the water is forced out, and the resulting stone is so hard, when removed from the mould, that it rings when struck. It will be evident to those acquainted with hydraulic mortars and the application of concrete, that this is only an improved concrete. The cost of production has been too great to admit of the general introduction of this artificial stone.

Ransome's Patent Siliceous Stone, being the most successful attempt to produce a permanent stone artificially, requires further attention.

After numerous failures, it occurred to Mr. Ransome that a solution of silica as a cementing material would be superior to any other, and he accordingly started on the inquiry after an easy method of producing a solution of flints.

The accompanying illustration (*fig.* 1913) gives a sectional view of the apparatus employed in preparing the solution of silica which Mr. Ransome employs.

1913



A is a steam-boiler, capable of generating a sufficiency of steam for heating the dissolving and evaporative vessels, and usually worked at a pressure of about 70 lbs. to the square inch. B is the upper lye-tank for dissolving the carbonate of soda. It is supplied with steam by the pipes 1, 2, 3, communicating with the boiler.

The first operation is to reduce the ordinary soda-ash of commerce to the condition of caustic soda. For this purpose the ash is first dissolved in the tank B, the water in which is heated by means of the perforated steam-pipe *b*. A quantity of quick-lime is then added, and the mixture well stirred. The soda is by this means deprived of the carbonic acid which it contains, by the quick-lime forming with it a carbonate of lime. To ascertain when the lye is quite caustic, a small portion is taken out in a test-tube, and a few drops of hydrochloric acid added. If there is no effervescence, it may be assumed that the soda is entirely deprived of its carbonic acid, and is consequently caustic, When the lime, now converted into chalk, has subsided to the bottom of the tank, the clear supernatant lye is drawn off by the syphon 5, into the funnel 6, leading into a closed vessel D, to prevent the carbonic acid of the atmosphere combining with it, and destroying its causticity. When the lye has been drawn off from B, the sediment remaining at the bottom of the tank is allowed to fall into the lower tank C, by withdrawing the plug *a*, from the pipe b^1. Any undissolved crystals of the carbonate of soda which have been entangled among the particles of the lime are now washed out and pumped back to the upper tank B, where it forms a portion of the next charge.

The clear caustic soda being contained in the closed tank D, has a further process of depuration to undergo before it is ready to be used as a solvent for the flints. The ordinary soda-ash of commerce is always more or less adulterated with a sulphate of soda, which although an inert substance in itself, if allowed to remain in the cement subsequently makes its appearance in an efflorescence on the surface of the finished stone. To get rid of the sulphate, the caustic solution of soda has added to it, in the tank D, a quantity of caustic baryta, obtained by burning the commercial carbonate of baryta with wood-charcoal. The caustic baryta seizes upon the sulphuric acid contained in the sulphate of soda, and forms with it an insoluble sulphate of baryta, which is precipitated on the bottom of the tank. The depurated lye is then drawn off by the pipe *d*, into the lower closed tank E, and the sulphate-of-baryta sediment passes off by the cock at the bottom. From E, the prepared solution of the caustic soda is pumped into the vertical boiler or digester F. This digester, in which the process of dissolving the flints is effected, is a cylindrical vessel, having a steam-jacket, *f*, into which steam from the boiler A is supplied by the pipes 1, 2, *y*. The inner cylinder F, is provided with a wire-basket G, reaching the whole length of the vessel, and serving to hold a collection of nodules of common flint. When F has been filled with the caustic lye, and the basket with flints, the manhole at the top is closed and well screwed down, so as to be able to resist a pressure of at least 60 lbs. on the square inch. The cock at *y* is then opened, and the full pressure of steam from the boiler passes into the jacket *f*, and causes the lye in F to rise to the same temperature. The condensed steam in the jacket *f* returns to the boiler by the pipe 12, which it enters below the water-line. The pressure maintained in the digester is generally about 60 lbs., and this is continued about 36 hours; at the end of which time the strength of the solution is tested. The workmen employed to superintend this part of the process generally use the tongue as the most delicate test. If the solution has a decidedly caustic alkaline taste, they conclude that there is still too much free soda in the cement, and the boiling is allowed to continue until the cement has a slightly sweetish taste, which occurs when the alkali has been nearly neutralised by combination with the silicic acid of the flints. A more scientific mode of testing the strength of the solution is to take a wine-glassful and drop a little hydrochloric acid into it; by this means the whole of the silica in the solution is thrown down by the acid combining with the soda, so as to form chloride of sodium. The precipitated silica presents an appearance resembling half-dissolved snow, and its comparative volume gives a good idea of the strength of the solution of the alkaline silicate.

When it is judged that the alkali has taken up as much of the silica as it is capable of doing, at the temperature to which it is subjected in the digester, the stop-cock *y*, in the steam-pipe communicating with the jacket, is shut, and a cock in the pipe 8 is opened. The pressure of the steam in F then forces the fluid silicate, through the pipe 8, into the vessel H, where it is allowed to stand for a short time to deposit any sediment which it may contain. From H it is then conveyed by the pipe 9 to the evaporating pan, K, which has a steam-jacket, *k*, supplied with steam by the pipe 10. The cement is then boiled in the evaporating pan until it becomes of the consistency of treacle, when it is taken out. The specific gravity of the cement when ready for use is about 1·600. The general proportions of the materials used in making up the artificial stone are about the following:—

10 pints of sand, 1 pint of powdered flint, 1 pint of clay, and 1 pint of the alkaline solution of flint.

These ingredients are first well mixed in a pug-mill, and kneaded until they are thoroughly incorporated, and the whole mass becomes of a perfectly uniform consistency. When worked up with clean raw materials, the compound possesses a putty-like consistency which can be moulded into any required form, and is capable of receiving very sharp and delicate impressions.

The peculiarity which distinguishes this from other artificial stones consists in the employment of silica both as the base and the combining material. Most of the varieties of artificial stone hitherto produced are compounds, of which lime, or its carbonate, or sulphate, forms the base; and in some instances they consist in part of organic matters as the cement, and having inorganic matters as the base.

To produce different kinds of artificial stone, adapted to the various purposes to which natural stones are usually applied, both the proportions and the character of the ingredients are varied as circumstances require. By using the coarser description of grits, grinding stones of all kinds can be formed, and that with an uniformity of texture never met with in the best natural stones. Any degree of hardness or porosity may also be given, by varying the quantity of silicate employed and subjecting it to a greater or less degree of heat.

For some descriptions of goods a portion of clay is mixed with the sand and other ingredients, for the double purpose of enabling the material to stand up during the process of firing in the kiln and to prevent its getting too much glazed on the surface.

The plastic nature of the compound allows of the most complex and undercut patterns being moulded with greater ease than by almost any other material we are acquainted with, if we except gutta-percha, which, however, has the drawback of being affected by common temperatures.

In attempting, however, to carry out this plan, Mr. Ransome found that two difficulties of a rather formidable character presented themselves. It was found that, in the process of desiccation, the surface of the stone parted with the moisture contained in the soluble silicate, and became hardened into a tough impervious coating, which prevented the moisture escaping from the interior of the mass. Any attempt to dislodge the water retained in combination with the silicate in the interior of the stone, by raising the temperature of the whole above 212°, had merely the effect of breaking this outer skin of desiccated silicate, and rendering the surface cracked and uneven.

Instead, therefore, of allowing the stones to be dried in an open kiln, they were placed in a closed chamber or boiler, surrounded with a steam-jacket, by which the temperature of the interior chamber could be regulated. In order that no superficial evaporation should take place while the stones were being raised to the temperature of the steam in the jacket, a small jet of steam was allowed to flow into the chamber, and condense among and on the surface of the goods; until, as the temperature of the interior of the stones rose to 212° and upwards, they became enveloped in an atmosphere of steam, which effectually prevented any hardening of the surface. The minute vents or spiracles formed by the steam as it was generated in the interior of the masses, remained open, when the vapour contained in the closed chamber was allowed slowly to escape, and afforded a means of egress to any moisture which might still be retained among the particles of sand and cement. The whole of the moisture contained in the silicate of soda having been thus vaporised before it left the stone, an opportunity was afforded it by opening a communication with the external atmosphere, to pass off, leaving the interior of the stone perfectly dry. Simple as this arrangement may seem, we will venture to say that not one of our readers has hit upon the expedient through his own cogitations on the subject.

The process, in effect, consists in stewing the stones in a closed vessel, and when all the moisture which they contain is converted into vapour, allowing it to escape, so that no one part of the mass can be dried before another. By this means Mr. Ransome was enabled to desiccate his artificial stone without any risk of the cracking or warping which had hitherto been the result of his attempts to harden them by exposure in an open stove.

After being thoroughly dried they are taken to the kiln, but, instead of being placed in *seggars* or boxes of clay, as is usually done in the potter's kiln, the goods are first bedded up with dry sand, to prevent any risk of their bending or losing their shape while burning. Flat slabs of fire-clay are then used to separate the various pieces laterally, and similar slabs are placed over them to form a shelf, on which another tier of goods is placed. The temperature of the kiln is very gradually raised for the first twenty-four hours; the intensity is then augmented until at the end of forty-eight hours a bright red heat is attained, when the kiln is allowed to cool gradually, for four or five days, when the goods are ready to be taken out.

From being composed almost entirely of pure siliceous matter, this artificial stone is not acted upon by acids, and is apparently quite insoluble, even in boiling water.

By proportioning the amount of cement, and varying the character of the sand which enters into the composition of the stone, it can be made porous or non-porous, as may be desired. The average absorbent power of artificial sandstone is less than that of the Bolsover Moor Dolomite used in the erection of the Houses of Parliament, and a little more than that of the Cragleith Sandstone.

An improvement in the manufacture of Ransome's Stone, or, as it is sometimes called *Apœnite*, was made and patented by the inventor in 1872.

It was found in practice that the process of washing the Ransome stone so as to completely remove all traces of the chloride of sodium, from large masses was open to objection; it was both tedious and expensive, especially in localities where there was a difficulty in obtaining a good supply of water at a reasonable cost, besides which in producing so large an amount of chloride of sodium which had afterwards to be removed as a waste product at a considerable cost. The bulk of the alkali, which was by far the most expensive ingredient in its composition, was ejected instead of being utilised, for still further increasing the density, strength, and hardness of the stone. Some years since a siliceous deposit was discovered at the base of the Chalk Hills in Surrey, possessing some very peculiar properties, amongst others, that of being readily soluble in a solution of caustic soda or potash at a moderately low temperature. Messrs. Paine and Way, in the 12th volume of the Journal of the Royal Agricultural Society, in a paper entitled 'On the Strata of the Chalk Formation,' thus describes the soluble silica deposit:—'Immediately above the gault, with the upper member of which it insensibly intermingles, lies a soft white-brown rock, having the appearance of a rich limestone. It is very remarkable on account of its low specific gravity, and still more so considering its position, by reason of the very small quantity of carbonate of lime which it contains. It is one of the richest subsoils of the whole chalk series, being admirably adapted for the growth of hops, wheat, beans, &c.

'The section of rock at Farnham is about 40 feet in thickness. The analysis gives as follows:—

	Per cent.
Combined water and a little organic matter	4·15
Soluble in dilute acids, 57·10:	
Silicic acid (silica)	46·28
Carbonic acid	none.
Sulphuric acid	trace.
Phosphoric acid	ditto.
Chlorine	none.
Lime	0·26
Magnesia	·07
Potash	·79
Soda	·43
Protoxide and peroxide of iron	6·12
Alumina	3·15
Insoluble in acids, 38·75:	
Lime	2·91
Magnesia	traces.
Potash	1·51
Soda	·60
Alumina, with a little oxide of iron	14·20
Silicic acid and sand	19·59
	100·00'

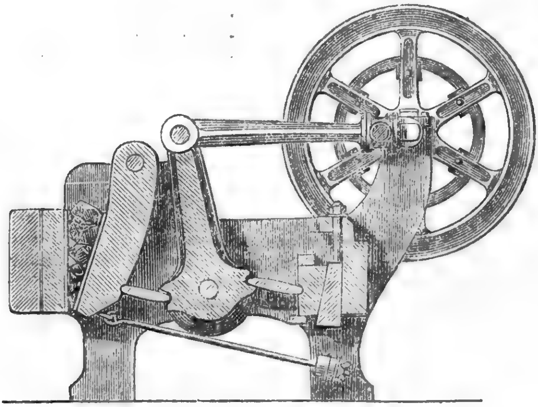
The same authors contributed another article to the 14th volume of the 'Journal,' on 'the Silica Strata of the Lower Chalk,' in which they state that 'when the former paper was published, they were not unaware that this stratum contained a large proportion of silica in the form which chemists call "soluble;" but that they wished, before making public their discovery, to ascertain whether it existed in sufficient quantity to render it available for agricultural use.' They then detail the result of their researches during the intervening two years, as far as they concern agriculture, mentioning all the localities in which this stratum may be found in England, and the various ways of employing it beneficially as a manure. They allude to the fact that it will be found useful in its application to the arts.

Taking advantage of this peculiarity, Mr. Ransome commenced a series of experiments, in order to determine if it were possible without the use of chloride of calcium, to produce a stone in all respects equal in quality to what had hitherto been made, and in this he succeeded. By mixing, in lieu of the chloride of calcium, suitable quantities of lime, (or substances containing lime), and the natural soluble silica above alluded to, with sand and a solution of silicate of soda or potash, which when intimately incorporated are moulded in the usual way, and allowed to harden gradually, as silicate of lime is formed by the decomposition of alkaline silicate produced by the action of the lime, the mass becomes thoroughly indurated, and in a very short time is converted into a very compact stone, capable of sustaining extraordinary pressure, and increasing in strength and hardness with age. Upon this improvement, Dr. T. Sterry Hunt makes the following remarks:—After expressing his satisfaction at the beautiful results arrived at by Mr. Ransome, who after years of experiment, had solved satisfactorily and completely a great industrial problem, he stated that he had followed with the more interest the labours of Mr. Ransome during many years, from the fact that he himself had formerly carried on, in 1857–58, a series of experiments very similar in character and in chemical results, in his endeavours to find out the method by which certain soft earthy rocks, consisting in great part of silica and carbonate of lime, have become hard and crystalline. Dr. Sterry Hunt had shown by researches in the laboratory, and also by observations of limestone strata in the vicinity of eruptive rocks, that a reaction between silica and carbonate of lime takes place in the presence of carbonate of soda, by which the alkali brought about, little by little, the solution of the silica, and its union with the lime to form a hard silicate of lime. This is nature's method. The action of alkali in dissolving the silica and then again giving it up to the lime, was an example of many of the so-called actions by presence, which are really cases of ordinary chemical affinity acting under peculiar conditions. It was reserved for Mr. Ransome, by using both the lime and the silica in their free, soluble and active forms, and by bringing in the alkali already combined with a portion of silica, to make this curious reaction very rapid, and to show that the product forms a cementing material which is available for binding particles of sand into hard stone-like masses. Mr. Ransome has also shown that the small amount of alkali used in the process itself, unites with the successive portions of silicate of lime formed, and becomes locked up in an insoluble compound, as is the case with alkali in granite rocks. Hence the new artificial stone, unlike the earlier products obtained by Mr. Ransome and by others, contains no soluble salts to be got rid of.

STONE- and ORE-CRUSHERS. Among the many modern forms of application, whereby mechanical devices are brought in aid of, and made to supersede, ordinary manual labour, there are few that have a wider range of utility than those which deal with the ores, stones, and rocks, and prepare them by reduction and comminution for the metallurgical and other processes on which so many of the arts and manufactures depend.

Mr. H. R. Marsden, of the Soho Foundry, Leeds, has long been known in connection with Blake's ore-crusher and stone-breaker, characterised by a peculiar 'toggle-motion.' The recent improvements are based substantially upon the Blake machine, but with novelties in details and in arrangement, constituting a new combination machine (see *fig.* 1914). An improved 'cubical' jaw is the most recent addition to the efficacy of these machines, for use when it is desirable or essential that the reduced material should be well and evenly broken up to a regular gauge and cubical form, as, more particularly in the case of road-metal. The construction of this jaw is simple, and consists in an extension of the lower end, and giving a curved form backwards to the moveable jaw; thus, the orifice of delivery is made to terminate a parallel channel of some 3 or 4 inches in length, wherein the corrugations of the fixed and moveable jaws are so arranged as to alternate the one with the other, *i.e.*, ridge against furrow, and *vice versâ*; and the action of this jaw leaves little to be desired in regard to the evenness and regularity of the resulting sample of broken stone; whence it is called 'cubical.' The combination of the steam-engine, crusher and screen upon one bed is generally adopted. This combined machine is useful for the breaking up and disintegration of all kinds of ores for the ironmaster and the miner in general. For these purposes the jaws can be changed according to the special degree of comminution desired; and this system is being adopted to replace rolls in various operations of grinding, on account of the fineness and evenness of the resulting material. A machine thus calculated to operate upon the most refractory materials, exercising powerful strains and destructive effects, while remaining itself comparatively unaffected, and capable of withstanding, without material depreciation, the great and 'constant' fatigue of such operations, is, it must be admitted, a valuable adjunct to the manufacturing processes in which it is available.

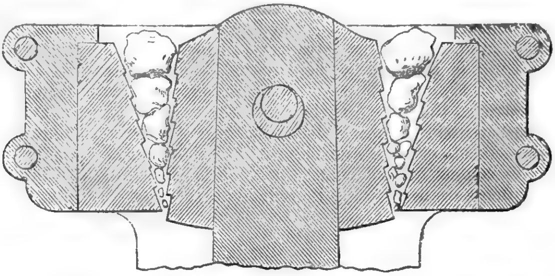
1914



Another stone- and ore-crushing machine has been introduced by Mr. J. C. Cole, of the Montpelier Ironworks, Walworth, and it is especially adapted for the production of concrete or for crushing to very small fragments any mineral or stone. It has become necessary of late to produce such machines as will cost the smallest amount for transit, at the same time being equal to any work; and the manner in which this apparatus appears to answer renders it an important adjunct to or in connection with stampers,

&c., as the material produced is very regular, and nothing escapes the jaws of this particular machine larger than $\frac{3}{8}$-inch cube, of which size it is capable of producing about 25 tons of material per day. The crushing jaws are arranged on each side of the main shaft, and at every revolution two strokes are given, which renders it double acting; and, if found necessary or requisite, one pair of jaws may be set to such a gauge as to produce larger material than the others, or both may be set either to a fine or coarse gauge (*fig.* 1915). In practice it is found necessary to reduce large pieces to about 2-inch cubes in one side of the machine. They are then placed in the other and reduced to fine material, and by this means a very large amount of work is done with very little power. The action of this machine will be readily understood without a drawing. All the bearings are protected from dust, and the apparatus is so simple that every part may be got at with ease. The machine does not weigh more than 30 cwts., and for mining enterprise, colonial or otherwise, this is of importance. There is no overflow, and all pieces of stone put into the hoppers are reduced in equal proportions. There are only three bearings in the whole apparatus. The crushing surfaces do not weigh more than 1 cwt. each, and are easily replaced.

1915



A powerful stone-crushing machine has also been introduced by Mr. Goodman.

STONE, PRESERVATION OF. The attention of the scientific world has for some time past been directed to the importance of providing a means for protecting the stone of our public buildings from the ravages of time and the injurious effects of the polluted atmosphere of our manufacturing and populous districts.

The principal cause of the ruinous decay which is so apparent in the national edifices, churches, mansions, &c., of this country, is generally admitted to be the absorption of water charged with carbonic or other acid gases, which by its chemical action either decomposes the lime or argillaceous matter forming the combining medium uniting the several siliceous or other particles of which the stone is composed, or mechanically disintegrates those particles by the alternate expansion and contraction caused by variations of temperature.

Many processes have from time to time been suggested, and several patents secured, for filling up the pores of the stone, and thus preventing the admission of these deleterious agents, but they have been mostly if not entirely composed of oleaginous or gummy substances or compounds, which, although possessing for a time certain preservative properties, become decomposed themselves upon exposure, and constantly require to be renewed; whilst from the nature of these applications the discoloration necessarily produced is highly objectionable.

The process of silicatisation introduced by Kuhlmann has the disadvantage of requiring some considerable time before the atmosphere can do its work of effecting the necessary combination between the silica applied in solution to the stone, and the lime contained in it, and therefore when it is applied to the external parts of any building it is liable to be washed out before solidification has been secured. Mr. Frederick Ransome, advancing from his siliceous-stone process a step farther, meets the condition by effecting a chemical change at once within the stone. Mr. Ransome thus describes his process:—

The mode of operation is simply this:—The stone or other material, of which a building may be composed, should be first cleaned by the removal of any extraneous matter on the surface, and then brushed over with a solution of silicate of soda or potash (the specific gravity of which may be raised to suit the nature of the stone or other material); this should be followed by a solution of chloride of calcium, applied also with a brush; the lime immediately combines with the silica, forming silicate of lime in the pores of the stone; whilst the chloride combines with the soda, forming chloride of sodium, or common salt, which is removed at once by an excess of water. From the foregoing description it will be apparent that this invention has not only rendered the operation totally independent of any condition of the atmosphere in completing the process, but the work executed is unaffected by any weather, even the most excessive rains. Experience has shown that where once applied to the stone it is impossible to remove it, unless with the surface of the stone itself.

The application is one of extreme simplicity, and the material used perfectly indestructible. The rationale of the process is thus explained:—A liquid will enter any porous body to saturation, whilst a solid cannot go any farther than the first interstices next the surface. Take, then, two liquids capable of producing, by mutual decomposition, a solid, and by the introduction of these liquids into the cells of any porous body, a solid is produced by their mutual decomposition internally; *ergo*, if a solid could not go in as a solid it cannot come out as a solid, and chemical decomposition having destroyed the solvents, they will never again be in a state of solution. The patentee has secured to himself the application of this important principle; and whilst we name silicate of soda and chloride of calcium as the agents under mutual decomposition by contact for producing the chloride of sodium and the imperishable silicate of lime, there are many other ingredients capable of producing like results.

Several large buildings in London—the Baptist Chapel in Bloomsbury, amongst others,—Glasgow, and other cities, have been treated with Mr. Ransome's process; a portion of the Houses of Parliament has been experimented on, and the result, so far as the time which has passed can test its merits, has been satisfactory.

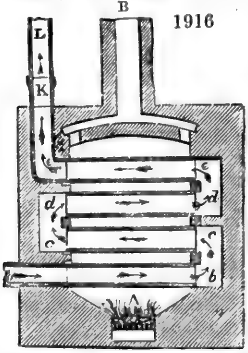
STONEWARE. (*Fäience*, Fr.; *Steingut*, Ger.) See POTTERY.

STORAX; STYRAX. *Liquid storax* is obtained from the storax plant, *Styrax officinale.* The finest is a pellucid liquid, having the consistency and tenacity of Venice turpentine, a brownish colour and a vanilla-like odour. The common, which is imported from Trieste in casks, is opaque, of a grey colour, and of the consistency of bird-lime. This has been frequently confounded with liquid-ambar. Storax is employed in perfumery, and yields an odour, when sufficiently dilute, exactly resembling the fragrance of the jonquil. See AMBAR, LIQUID; PERFUMERY.

Common storax; Styrax calamita.—This is imported in large round cakes, of a brown or reddish-brown colour. 'It appears to consist of some liquid resin mixed with fine sawdust or bran.'—*Pereira.*

Storax in the tear.—This is imported in yellowish or reddish-white tears, about the size of peas. There are some other varieties, but these are not of sufficient importance to be noticed here. Storax has but little use, except as a pharmaceutical article.

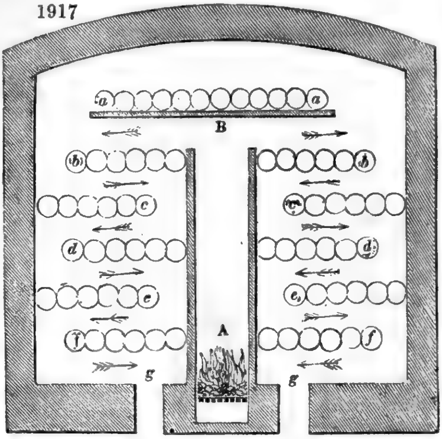
STOVE (*Poêle, Calorifère*, Fr.; *Ofen*, Ger.) is a fire place, more or less close, for warming apartments. When it allows the burning coals to be seen, it is called a stove-grate. Hitherto stoves have rarely been had recourse to in this country for heating our sitting-rooms; the cheerful blaze and ventilation of an open fire being generally preferred. Some arrangements have been introduced for close stoves, in which charcoal or coke was burnt, and which required little or no chimney. When coke or charcoal is burned very slowly in an iron box, the carbonic acid gas which is generated, being half as heavy again as the atmospheric air, cannot ascend in the chimney at the temperature of 300° Fahr.; but regurgitates into the apartment through every pore of the stoves, and poisons the atmosphere. The large stoneware stoves of France and Germany are free from this vice; because, being fed with fuel from the outside, they cannot produce a reflux of carbonic acid into the apartment, when their draught becomes feeble, as inevitably results from the obscurely burning stoves which have the doors of the fireplace and ash-pit immediately above the hearth-stone.


1916

Stoves when properly constructed may be employed both safely and advantageously to heat entrance-halls upon the ground story of a house; but care should be taken not to vitiate the air by passing it over ignited surfaces, as is the case with most of the patent stoves now foisted upon the public. *Fig.* 1916 exhibits a vertical section of a stove which has been recommended for power and economy; but it is highly objectionable as being apt to scorch the air. The flame of the fire A, circulates round the horizontal pipes of cast iron, *b b, c c, d d, e e,* which receive the external air at the orifice *b*, and conduct it up through the series, till it issues highly heated at K, L, and may be thence conducted wherever it is wanted. The smoke escapes through the chimney B. This stove has evidently two prominent faults: first, it heats the air-pipes very unequally, and the undermost far too much; secondly, the air, by the time it has ascended through the zigzag range to the pipe *e e*, will be nearly of the same temperature with it, and will therefore abstract none of its heat. Thus the upper pipes, if there be several in the range, will be quite inoperative, wasting their warmth upon the sooty air.

Fig. 1917 exhibits a transverse vertical section of a far more economical and powerful stove, in which the above evils are avoided. The products of combustion of the fire A, rise up between two brick walls, so as to play upon the bed of tiles B, where, after communicating a moderate heat to the series of slanting pipes whose areas are represented by the small circles *a a*, they turn to the right and left, and circulate round the successive rows of pipes, *b b*, *c c*, *d d*, *e e*, and finally escape at the bottom by the flues *g*, *g*, pursuing a somewhat similar path to that of the burned air among a bench of gaslight retorts. It is known that two-thirds of the fuel have been saved in the gasworks by this distribution of the furnace. For the purpose of heating apartments, the great object is to supply a vast body of genial air; and, therefore, merely such a moderate fire should be kept up in A, as will suffice to warm all the pipes pretty equally to the temperature of 220° Fahr.; and, indeed, as they are laid with a slight slope, are open to the air at their under ends, and terminate at the upper in a common main pipe or tunnel, they can hardly be rendered very hot by any intemperance of firing. If the tubes be made of stoneware, its construction will cost very little; and they may be made of any size, and multiplied so as to carry off the whole effective heat of the fuel, leaving merely so much of it in the burned air as to waft it fairly up the chimney.

1917



Open fire places are, and probably will ever remain, favourites in this country. There is no doubt that the ordinary arrangement of our fireplaces is very defective. Much heat is lost—there is not an equal diffusion, and those sitting in the apartment are exposed to annoying draughts of cold air. Arranged as our buildings are, it is not easy to perceive how any very great improvement could be made so long as we desire the enjoyment of an open fire and the luxury of light and air.

In the greater number of stoves proper, the objections are obvious to every one. In the more common kinds of stove the fire is surrounded directly by the surface to be heated, which, being placed unprotected in the room, radiates heat and warms the air by direct contact. All such are liable to become overheated, and then the unpleasant smell imparted to the air is highly objectionable. Such stoves also dry the air, and the result is that headaches and other annoying sensations are produced. The common stoves need not be described. Dr. Arnott introduced, many years since, a stove in which the arrangements were very complete; and as the combustion was regulated with much facility, they were economical. The chief feature of Arnott's stove was a mode of adjusting the amount of air supplied to the fire. A regulating valve is fitted to the aperture of the ash-pit, consisting of a frame nicely balanced, and turning with the slightest force upon a centre; to this is attached a steel-yard, in which are several holes for the insertion of a weight. This determines exactly the size of the opening, and of course regulates the quantity of air admitted to the fire.

In these stoves there is a tendency, when the stove is not heated above 250° or 300°, to the formation of considerable quantities of carbonic acid, which finds its way into the room from the ashpit-door; and when the combustion is languid, carbonic oxide is often formed, which passes away by the chimney unconsumed, involving a loss of heat.

Space will not admit of our describing the Dutch or American stoves, which are mainly modifications of the ordinary forms, which are sufficiently well known.

It would, perhaps, be no exaggeration to say that with close stoves, heating apparatus, and other arrangements, in which there is no appearance of warmth, a *much higher temperature of the atmosphere is required to make it even feel* as warm as in that of an apartment heated by an open fire. Indeed, it may be fairly asserted that most persons will tolerate inconvenience and submit to expense, provided they see the cheerful blaze of the open fire, which they are at liberty to approach at will.

One of the large pyro-pneumatic stove-grates, when in full operation, is found to be capable of heating an apartment containing 50,000 cubic feet of air. In a very large church, containing upwards of 175,000 cubic feet of air, and capable of accommodating a congregation of 1,500 persons, four of these stoves of moderate size, arranged in convenient positions towards the angles of the building, so that every individual of the congregation may see the fire, are found to be sufficient in the coldest weather, and do not even require to be sustained in full action, except during a few hours in the morning. One of these stove-grates placed in the hall or lower part of a staircase, warms and tempers the internal climate of a large house, and gives the whole building a plentiful supply of pure fresh air. One of the smaller grates is capable of warming a large room. And whether in dwelling-houses, schools, churches, or apartments, the arrangements can readily be brought into operation at a moderate cost, and without any (beyond the most trifling) interference with existing structural arrangements.

STRAHLKIES. The German name for radiated pyrites.

STRAHLSTEIN. The fibrous varieties of hornblende (actinolite) are known to German mineralogists under this name. See Hornblende.

STRASBURG TURPENTINE. See Abies.

STRASS. See Pastes.

STRATA. Sedimentary rocks are generally spread out in layers called *strata*, whence they are known as *stratified rocks*. These strata exhibit a definite sequence; and the following table will show the order in which the several 'formations,' or groups of fossiliferous strata succeed each other in the British Isles, commencing with the uppermost, or most recent:—

1. *Tertiary* or *Cainozoic.*		2. *Secondary* or *Mesozoic.*		3. *Primary* or *Palæozoic.*
Pliocene.	Cretaceous.	Chalk.		Permian.
Miocene.		Upper Greensand.	Carboniferous.	Coal-Measures.
Eocene.		Gault.		Millstone Grit.
		Neocomian.		Yoredale Rocks.
		Wealden.		Devonian.
	Jurassic.	Purbeck.	Upper Silurian.	Ludlow.
		Portland.		Wenlock.
		Kimmeridge Clay.		Upper Llandovery.
		Coral Rag.	Lower Silurian.	Lower Llandovery.
		Oxford Clay.		Bala Beds.
		Cornbrash.		Llandeilo.
		Great Oolite.		Arenig.
		Inferior Oolite	Cambrian.	Tremadoc Slates.
		Lias.		Lingula Flags.
		Rhætic Beds.		Menevian.
		Trias.		Laurentian.

STRAWBERRY. The fruits of various species of *Fragaria*, such as *F. vesca*, *F. elatior*, &c. They belong to the natural order *Rosaceæ*.

STRAW-HAT MANUFACTURE. The mode of preparing the Tuscany or Italian straw is by pulling the bearded wheat while the ear is in a soft milky state, the corn having been sown very close, and of consequence produced in a thin, short, and dwindled condition. The straw, with its ears and roots, is spread out thinly upon the ground in fine hot weather, for 3 or 4 days or more, in order to dry the sap; it is then tied up in bundles and stacked, for the purpose of enabling the heat of the mow to drive off any remaining moisture. It is important to keep the ends of the straw air-tight, in order to retain the pith, and prevent its gummy particles from passing off by evaporation.

After the straw has been about a month in the mow, it is removed to a meadow and spread out, that the dew may act upon it, together with the sun and air, and promote the bleaching, it being necessary frequently to turn the straw while this process is going on. The first process of bleaching being complete, the lower joint and root is pulled from the root, leaving the upper part fit for use, which is then sorted according to qualities; and after being submitted to the action of steam, for the purpose of extracting its colour, and then to a fumigation of sulphur, to complete the bleaching, the straws are in a condition to be platted or woven into hats and bonnets, and are in that state imported into England in bundles, the dried ears of the wheat being still on the straw.

Straw cannot be bleached by a solution of chloride of lime, as this preparation always turns the straw yellow. For this purpose, a cask open at both ends, with its seams papered, is to be set upright a few inches from the ground, having a hoop nailed to its inside, about six inches beneath the top, to support another hoop with a net stretched across it, upon which the straw is to be laid in successive handfuls loosely crossing each other. The cask having been covered with a tight overlapping lid, stuffed with lists of cloth, a brazier of burning charcoal is to be inserted within the bottom, and an iron dish containing pieces of brimstone is to be put upon the brazier. The brimstone soon takes fire, and fills the cask with sulphurous acid gas, whereby the straw gets bleached in the course of three or four hours. Care should be taken to prevent such a violent combustion of the sulphur as might cause black burned spots, for these cannot be afterwards removed. The straw after being aired and softened by spreading it on the grass for a night, is ready to be split, preparatory to dyeing. Blue is given by a boiling-hot solution of indigo in sulphuric acid, called *Saxon blue*, diluted to the desired shade; yellow, by decoction of turmeric; red, by boiling hanks of coarse scarlet wool in a bath of weak alum-water, containing the straw; or directly, by cochineal salt of tin, and tartar. Brazil-wood and archil are also employed for dyeing straw. For the other colours, see their respective titles in this Dictionary.

STREAM-WORKS. The name given by the Cornish miners to alluvial deposits of tin ore.

STREET MUD. This is a day of utilisation. We have already found out plans for turning old clothes into money, for making our fields fertile by using the refuse, and now the proverb 'cheap as dirt' seems likely to lose all its force. 'The Engineer,' speaking of the wet mud called 'Macadam milk,' which covers the streets of Paris in the rainy season, says: 'An adventurous individual has found an application for this stuff, and at the same time, it is said, an income of 400*l.* a year for himself. He collects the "milk," allows it to settle in large tanks, passes the precipitate through silk sieves, and forms it afterwards into what we call Flanders bricks for knife-cleaning, which sell at a franc each.'

Upon this Mr. John Phillips remarks, 'that by a similar process, and from similar material, stone or brick for cleaning or polishing steel and brass, and which is locally known as "rotten stone," has been for many years, and still is, manufactured at the Aller Works, near Newton Abbot. The roads in the neighbourhood which supply the raw material are macadamised with flints, which especially adapts it for this purpose. If credit is due anywhere for this utilisation of waste, let it not be monopolised by France, but let Devonshire claim its fair share.'

STRETCHING MACHINE. Cotton goods and other textile fabrics, either white or printed, are prepared for the market by being stretched in a proper machine, which lays all their warp and woof yarns in truly parallel positions. A very ingenious and effective mechanism of this kind was made the subject of a patent by Mr. Samuel Morand, of Manchester, in April 1834, which serves to extend the width of calico pieces, or of other cloths woven of cotton, wool, silk, or flax, after they have become shrunk in the processes of bleaching, dyeing, &c. The limits of this volume will not admit of its description, The Specification of the patent is published in 'Newton's Journal' for December 1835.

STRINGS, a *miner's term.* The name given by the Cornish miners to the small filamentous ramifications of a metallic vein.

STRINGY-BARK TREES. The great stringy-bark gum-trees of Australia are various species of *Eucalyptus.* They are so called in consequence of the bark separating in fibrous layers.

STRIPPING LIQUID, SILVERSMITH'S, consists of 8 parts of sulphuric acid and 1 part of nitre.

STROMEYERITE. A sulphide of copper and silver, found in Siberia, Silesia, Chili, and Peru.

STRONTIA (*oxide of strontium*, SrO), one of the alkaline earths, of which *strontium* is the metallic basis, occurs in a crystalline state, as a carbonate (*strontianite*) in the lead mines of Strontian in Argyleshire—whence its name. The sulphate (*celestine*) is found crystallised near Bristol, in New Red marl, and in several other localities; but strontian minerals are rather rare. The pure earth is prepared exactly like baryta, from either carbonate or the sulphate. It is a greyish-white porous mass, infusible in the furnace, not volatile, of a specific gravity between 3·0 and 4·0: 3·9231 (*Karsten*); having an alkaline reaction on vegetable colours, an acrid, burning taste, sharper than lime, but not so corrosive as baryta, potash, or soda. It becomes hot when moistened, and slakes into a white pulverulent hydrate, dissolves at 60° in 50 parts of water, and in much less at the boiling point, forming an alkaline solution, called *strontia*-water, which deposits crystals in four-sided tables as it cools.

These contain 60·9 per cent. of water, are soluble in 52 parts of water at 60° and in 2·4 parts of boiling water; when heated they part with 50 per cent. of water, but retain the other parts, even at a red heat. The dry earth consists of 84·6 of base, and 15·4 of oxygen. It is readily distinguished from baryta, by its inferior solubility, and by its soluble salts giving a red tinge to flame, while those of baryta give a greenish tinge. Fluosilicic acid precipitates the salts of the latter earth, but not those of the former. The compounds of strontia are not poisonous, like those of baryta. The only preparation of strontia used in the arts is the Nitrate.—H. W. B.

STRONTIA, CARBONATE OF. $SrO.CO^2$ ($\mathbf{SrCO^3}$). See Strontianite.

STRONTIA, NITRATE OF. $SrO.NO^5$ [$\mathbf{Sr(NO^3)^2}$]. *Nitrate de strontiane*, Fr.; *Salpetersaurer Strontian*, Ger.) This salt is usually prepared from the sulphide of strontium, obtained by decomposing the sulphate with charcoal, by strong ignition of the mixed powders in a crucible. This sulphide being treated with water, and the solution being filtered, is to be neutralised with nitric acid, as indicated by the test of turmeric-paper; care being taken to avoid breathing the noxious sulphuretted hydrogen gas, which is copiously disengaged. The neutral nitrate being properly evaporated and set aside, affords colourless, transparent, slender, octahedral crystals. It has a cooling, yet somewhat acrid taste; is soluble in 5 parts of cold, and in one half-part of boiling water. Its principal use is the preparation of 'red fire' for pyrotechnic works and theatrical effects. A very beautiful exhibition of red fire is obtained by preparing a gun-paper, by treating ordinary bibulous paper with nitric and sulphuric acids, and then well washing it; when quite free from acid, it is to be dried, and then saturated with a solution of the chloride or nitrate of strontia.—H. W. B. See Pyrotechny.

STRONTIA, SULPHATE OF. $SrO.SO^3$ ($\mathbf{SrSO^4}$). See Celestine.

STRONTIANITE. Native carbonate of strontia.

STRONTIUM. The metallic base of the earth strontia; first obtained by Sir Humphry Davy, in 1808. It is prepared in the same way as barium. See Barium. See Watts's 'Dictionary of Chemistry.'

STRYCHNINE. $C^{42}H^{22}N^2O^4$ ($\mathbf{C^{21}H^{22}N^2O^2}$). The bitter poisonous principle contained in the different *species* of *Strychnos*. It is usually extracted for commercial purposes from the nux-vomica bean, the seed of the *S. nux vomica*. It is a well-marked alkali, and yields a great number of crystalline salts with acids and metallic chlorides. Its true constitution has been fully made out by the researches of Messrs. Nicholson and Abel. Although a most valuable medicine in paralytic affections, when employed in very small doses, it is a dangerous remedy in unskilful hands, and has been the cause of numerous deaths arising from carelessness, without reckoning the many who have been destroyed by it at the hands of the poisoner. Some years ago a panic was occasioned by a rumour of its employment for the purpose of giving a bitter flavour to beer; this has been shown to be incorrect. Still the quantities of it produced annually by various manufacturers could not fail to excite attention and uneasiness. As much as 1,000 ounces have been known to be purchased at one time. It has been proved, however, that the chief use is for the destruction of wild animals in Australia and other thinly-peopled localities. A great number of processes have been devised for its preparation; but, after having been subjected to the extractive operations, the bean is generally found almost as bitter as before, indicating a want of economy in the methods. Probably the best method of extraction would be to disintegrate the beans with strong sulphuric acid (which is without action on strychnine), and then, after the addition of excess of alkali, to dissolve out the base with benzole or chloroform. The latter being distilled off would leave the strychnine nearly pure, and only requiring crystallisation. It has been shown by John Williams, that one bean will by this process yield a considerable quantity of crystals of pure strychnine.

STUCCO. See Stone, Artificial.

SUBERIC ACID (from *Suber*, Lat. 'cork;' *Korksäure*, Ger.) is prepared by digesting grated cork with nitric acid. It forms crystals, which sublime in white vapours when heated.

It may also be obtained by boiling nitric acid with stearic, margaric, or oleic acids.

SUBLIMATE, is any solid matter resulting from condensed vapours. See Corrosive Sublimate.

SUBLIMATION, the process by which volatile matter is evaporised by heat, and then condensed into a crystalline mass. For example, if gum benzoin is kept in a melted state, and even a cap of paper kept above it, the benzoic acid is first volatilised, and then condensed on the paper. For an example of sublimation, see Ammonium, Chloride of.

SUBMARINE LAMP. M. J. D. Pasteur, of Gennep, has invented a very simple and ingenious lamp for the use of divers. The great expense and trouble connected with the use of the electric light for diving apparatus led M. Pasteur to form the idea of a much cheaper and more practical lamp to burn under water; how the atmospheric air under pressure in the helmet of the diver, by means of the air-pump, is but partially deteriorated, and M. Pasteur tried to examine whether the remaining oxygen was still sufficient to maintain the light of an ordinary petroleum-lamp. The trial which he made for that purpose succeeded perfectly. On the opening in the helmet, where, by means of the valve, the consumed air escapes into the water, is screwed an India-rubber tube, ¾-inch diameter and 4 feet long, to which the water-tight lamp was attached. The side on which the air enters the lamp was, as in the helmet, divided in such a way as to prevent the light from being blown out, and to distribute the air, as much as possible, under and around the flame. The little valve-spindle, placed upon the helmet to prevent the entrance of the water, was taken away and put on the top of the lamp. Behind the light was placed a parabolic mirror, and on the front side a convex glass; to the back was fitted a crook to carry the lamp, whether in the hand or on the breast. M. Pasteur had the satisfaction to read with this lamp under water small hand-writing, and observed at the same time that neither the carbonic acid nor the vapour of water breathed out by the diver had any influence on the illuminating powers of the flame.

SUCCINIC ACID, or *Acid of amber* (*Acide succinique*, Fr.; *Bernsteinsäure*, Ger.), was formerly obtained by the destructive distillation of amber, in which process it was accompanied by an essential oil, and a little acetic acid; it was purified by being precipitated as succinate of lead, which, after being well washed, was decomposed by the equivalent quantity of sulphuric acid; the solution of succinic acid, thus obtained, was evaporated, and allowed to cool, when the succinic acid crystallised out. It seems to exist ready formed in amber.

It is easily obtained artificially by acting on stearic or palmitic acid with nitric acid. It also occurs in the leaves of the wormwood, and in many of the resins of the pine tribe. It may likewise be obtained by fermentation from asparagin, and from malic acid, malate of lime yielding nearly one-third of its weight of it.

In order to produce it from malic acid, 3 lbs. of crude malate of lime are to be diffused through a gallon of warm water, and 4 ounces of decayed cheese added to the mixture, which is to be kept at the temperature of 100° for about a week. Carbonic acid is disengaged, whilst a mixture of crystallised carbonate and succinate of lime is deposited, and acetate of lime remains in solution.

SUCCINITE. Prof. Dana has applied this name to the insoluble resin which forms about 80 per cent. of amber. See AMBER.

SUET. The internal fat of the abdomen of the sheep. See TALLOW.

SUGAR (*Sucre*, Fr.; *Zucker*, Ger.) is, with some slight exception, the sweet constituent of vegetable and animal products. It may be distinguished into three principal species. The first, which occurs in the sugar-cane, the beet-root, and the maple, crystallises in oblique four-sided prisms, terminated by two-sided summits; it has a sweetening power, which may be represented by 100; and in circumpolarisation it bends the luminous rays to the right. The second occurs ready formed in ripe grapes and other fruits; it is also produced by treating starch with diastase or sulphuric acid. This species forms cauliflower concretions, but not true crystals; it has a sweetening power, which may be represented by 60; and in circumpolarisation it bends the rays to the left. Berthelot has shown that a moderately strong solution of glycerine, in contact with certain animal membranes, is found, after some weeks, to produce a substance with the properties of grape-sugar. One pint of glycerine in 10 pints of water is added to the membrane, which may amount to $\frac{1}{20}$th of the weight of the glycerine. The time required is 10 to 12 weeks. If putrefaction begins, it is destroyed. The third variety is found in fruits, and also in sugar which has been long boiled, or heated with acids; this is called fruit-sugar. Besides these three principal kinds, the sugar of milk, and the sugar of manna or *mannite*, are found closely allied, and may be called two other species. Allied to these is *sorbine*, extracted from the elderberry, and *mosite*, which occurs in the flesh of animals.

Sugar, extracted either from the cane, the beet, or the maple, is identical in its properties and composition, when refined to the same pitch of purity; that of the beet is said to surpass the other two, since larger and firmer crystals of it are obtained from a clarified solution of equal density. Sugar melts at 320° Fahr., and on cooling forms a transparent substance usually called *barley-sugar*. When heated to between 400° and 410° Fahr. it loses two equivalents of water and becomes brown. Sugar thus fused is no longer capable of crystallisation, and is called *caramel* by the French, and is used for colouring liqueurs. Indeed, sugar is so susceptible of change by heat, that if a colourless solution of it be exposed for some time to the temperature of boiling water, it becomes brown and partially uncrystallisable. Acids exercise such an injurious influence upon sugar, that after remaining in contact with it for a little while, though they be rendered thoroughly neutral, a great part of the sugar will refuse to crystallise. Thus, if oxalic or tartaric acid be added to sugar in solution, and boiled, no crystals of sugar can be obtained by evaporation, even though the acids be neutralised by chalk or carbonate of lime. By boiling cane-sugar with dilute sulphuric acid, and keeping it at least at 150° Fahr., it is changed into grape-sugar, and then entirely into uncrystallisable sugar. Nitric acid converts sugar into oxalic acid. Alkaline matter is likewise most detrimental to the grain of sugar; as is always evinced by the large quantity of molasses formed when an excess of lime has been used in clarifying the juice of the cane or the beet.

Manufacturers of sugar should, therefore, be particularly watchful against the formation of acid from decomposition, or the introduction of any excess of alkali, or alkaline earth.

Sugar is soluble in all proportions in water, but it takes four parts of spirits of wine of spec. grav. 0·830, and 80 of absolute alcohol, to dissolve it, both being at a boiling temperature. As the alcohol cools, it deposits the sugar in crystals. Carmelised and uncrystallisable sugar dissolve readily in alcohol. Pure sugar is unchangeable in the air, even when dissolved in a good deal of water, if the solution be kept covered in the dark; but with a very small addition of gluten, the solution soon begins to ferment, whereby the sugar is decomposed into alcohol and carbonic acid, by the action of the air; it then passes into acetic acid, when it may be still farther decomposed.

Sugar forms chemical compounds with the salifiable bases. It dissolves readily in caustic potash-lye, whereby it looses its sweet taste, and affords on evaporation a mass which is insoluble in alcohol. When the lye is neutralised by sulphuric acid, the sugar recovers partially its sweet taste, and may be separated from the sulphate of potash by alcohol, but it will no longer crystallise.

Cane-sugar is soluble in all proportions in boiling water, and in $\frac{1}{3}$ of cold.

It is sparingly soluble in alcohol of 70 pc. and insoluble in absolute alcohol. The following table, by Payen, shows the quantity of sugar contained in saccharine solutions of various specific gravity at 59° Fahr.:—

Parts of sugar		Parts of water		Specific gravity
100	dissolved in	50	give a syrup of	1·345
100	„	60	„	1·322
100	„	70	„	1·297
100	„	80	„	1·281
100	„	90	„	1·266
100	„	100	„	1·257
100	„	120	„	1·222
100	„	140	„	1·200
100	„	160	„	1·187
100	„	180	„	1·176
100	„	200	„	1·170
100	„	250	„	1·147
100	„	350	„	1·111
100	„	450	„	1·089
100	„	550	„	1·074
100	„	650	„	1·063
100	„	750	„	1·055
100	„	945	„	1·045
100	„	1145	„	1·030
100	„	1945	„	1·022
100	„	2445	„	1·018
100	„	2945	„	1·015

The following table appeared in a previous edition of this work, and has been much used:—

Sugar in one hundred parts by weight	Sp. gr. at 60°	Sugar in one hundred parts by weight	Sp. gr. at 60°
66·666	1·3260	25·000	1·1045
50·000	1·2310	21·740	1·0905
40·000	1·1777	20·000	1·0820
33·333	1·1400	16·666	1·0685
31·250	1·1340	12·500	1·0500
29·412	1·1250	10·000	1·0395
26·316	1·1110		

The annexed table, constructed by Neimann for the normal temperature of 63°, with the same object, will be found useful:—

Sugar	Water	Specific gravity	Sugar	Water	Specific gravity
0	100	1·0000	36	64	1·1582
1	99	1·0035	37	63	1·1631
2	98	1·0070	38	62	1·1681
3	97	1·0106	39	61	1·1731
4	96	1·0143	40	60	1·1781
5	95	1·0179	41	59	1·1832
6	94	1·0215	42	58	1·1883
7	93	1·0254	43	57	1·1935
8	92	1·0291	44	56	1·1989
9	91	1·0328	45	55	1·2043
10	90	1·0367	46	54	1·2098
11	89	1·0410	47	53	1·2153
12	88	1·0456	48	52	1·2209
13	87	1·0504	49	51	1·2265
14	86	1·0552	50	50	1·2322
15	85	1·0600	51	49	1·2378
16	84	1·0647	52	48	1·2434
17	83	1·0698	53	47	1·2490
18	82	1·0734	54	46	1·2546
19	81	1·0784	55	45	1·2602
20	80	1·0830	56	44	1·2658
21	79	1·0875	57	43	1·2714
22	78	1·0920	58	42	1·2770
23	77	1·0965	59	41	1·2826
24	76	1·1010	60	40	1·2882
25	75	1·1056	61	39	1·2933
26	74	1·1103	62	38	1·2994
27	73	1·1150	63	37	1·3050
28	72	1·1197	64	36	1·3105
29	71	1·1245	65	35	1·3160
30	70	1·1293	66	34	1·3215
31	69	1·1340	67	33	1·3270
32	68	1·1388	68	32	1·3324
33	67	1·1436	69	31	1·3377
34	66	1·1484	70	30	1·3440
35	65	1·1538			

The specific gravity of crystallised cane-sugar is 1·594. Crystallised cane-sugar seems to be the most complete type of sugar known. Its crystals are the largest and most regular, and its taste the sweetest. These crystals are rhomboïdal prisms, and appear largest in the form of sugar-candy. When boiled much or heated with acids it would appear that a lower form of sugar resulted, namely, grape-sugar.

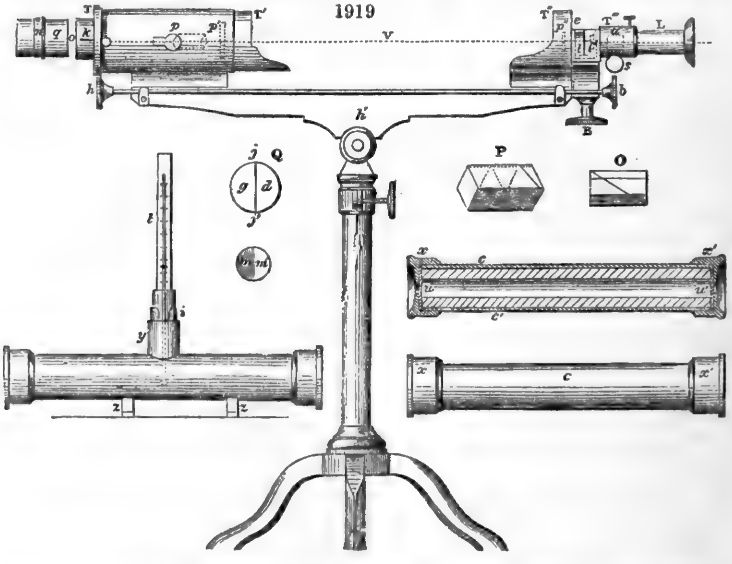
At 300° sugar loses 0·6 per cent., and remains uninjured after seven hours; it melts at 320°, and at this point it seems to have lost some of its sweetness, and probably a portion of water. The same result is obtained at a lower temperature if more time is allowed. The colour is changed to an orange-yellow at 410°: the sugar loses three equivalents of water, becomes gradually brown, has an empyreumatic taste, and is called *caramel*. With a heat approaching to a red heat, carburetted hydrogen, carbonic acid, acetic acid, and empyreumatic oils are produced, and carbon remains, amounting to 25 per cent. of the original mass.

Solutions of sugar are decomposed by caustic alkaline solutions, and by hot solutions of the carbonated fixed alkalis. Under these must be included both baryta and lime, if heat is to be long used: both of these substances form compounds with sugar. The compound of sugar and lime is very soluble in cold water, but is precipitated on heating. The amount dissolved is shown to be of true equivalent, by the inquiries of Peligot, who has proposed an ingenious method of ascertaining the amount of sugar in a solution by the estimation of the lime which it will dissolve. The lime in this process is estimated alkalimetrically by means of an acid. The following table has been constructed by M. Peligot for calculating the results (see next page).

Saccharimetry.—We now come to the estimation of sugar, which is most simply performed by the hydrometer, when the solutions are pure and the kind of sugar known. But commercially it is required to ascertain the proportions of cane-sugar, uncrystallisable sugar, water, and impurities, and this is accomplished most successfully

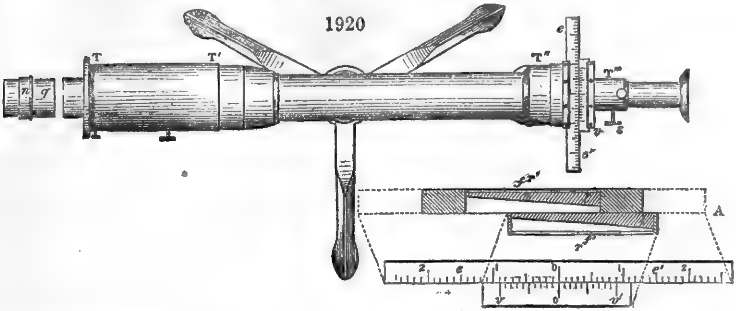
Quantity of sugar dissolved in 100 parts of water	Density of syrup	Density of syrup when saturated with lime	100 parts of residue dried at 120° contain	
			Lime	Sugar
40·0	1·122	1·179	21·0	79·0
37·5	1·116	1·175	20·8	79·2
35·0	1·110	1·166	20·5	79·5
32·5	1·103	1·159	20·3	79·7
30·0	1·096	1·148	20·1	79·9
27·5	1·089	1·139	19·9	80·1
25·0	1·082	1·128	19·8	80·2
22·5	1·075	1·116	19·3	80·7
20·0	1·068	1·104	18·8	81·2
17·5	1·060	1·092	18·7	81·3
15·0	1·052	1·080	18·5	81·5
12·5	1·044	1·067	18·3	81·7
10·0	1·036	1·053	18·1	81·9
7·5	1·027	1·040	16·9	83·1
5·0	1·018	1·026	15·3	84·7
2·5	1·009	1·014	13·8	86·2

by means of the polarising saccharometer proposed by Biot and improved by Soleil. The following is a description of this beautiful instrument:—Two tubular parts, T T′, and T″ T‴, *figs.* 1919 and 1920, constitute the principal part of the saccharometer. The light enters *n*, through a Nicol's prism *q* (shown separately, *fig.* 1919, at O), and passes first an achromatic polarising prism *p* (shown separately at P) and afterwards through a plate of quartz of double rotation at *p*′, which is also shown at Q. This plate is composed of two semi-discs cut perpendicularly to the axis of crystallisation; but though exactly of equal thickness and equal rotating power, the one turns the ray to the right, while the other turns it to the left. At *p*″, the ray passes a plate of quartz of single rotation, and at *l l*′, two wedges of quartz endued with the power of rotation, but in a contrary direction to the preceding plate. These two wedges are again represented at A (*fig.* 1920), and are so made that by turning the milled head B, the sum of their thicknesses can be increased or diminished at pleasure, while the amount of thickness is shown by the ivory graduated scale *e e*′, and vernier *v v*′. Finally, the ray


1919

traverses an analysing prism *a*, and an eye-piece L. If the instrument is directed to the light the observer will see a luminous disc, bisected by a central line (produced by the junction of the two semi-discs of quartz) of exactly the same tint, but which tint may be varied at pleasure, by rotating the Nicol's prism *n*, by means of the milled head *b*. If, however, we interpose between *p′* and *p″*, the tube *c*, *fig.* 1919, filled with a solution of cane-sugar, and the ends closed with glass, the semi-discs will be *differently coloured.* Cane-sugar, possessing the power of circular polarisation, combines with the rotating power of the half-disc which turns the ray to the right, but tends to neutralise the half-disc, whose direction is the reverse. By increasing or diminishing the thickness of the wedges of quartz *l l′*, to the extent required for counteracting their rotation to the right, and causing the semi-discs to reassume the same colours, we have a means by the graduated scale *e e′*, *v v′*, of measuring the rotating power, which is exactly proportional to the amount of cane-sugar, temperatures being equal, and no foreign substance having the power of circular polarisation being present.

1920



To apply this method, the deviation must be known which is produced by a solution of sugar of known strength. For this purpose a given weight, ϵ, of sugar is dissolved in such a quantity of distilled water that the solution occupies a given volume, V. Sufficient of this solution is taken to fill a tube of certain length, and the deviation suffered by the plane of polarisation of the luminous ray passing through this tube is measured. Let this deviation be α. Let then other quantities of sugar be dissolved in sufficient water to give the same volume of solution, V; and let the deviations produced by these solutions in the same tube be α', α'', α''', &c.; then the quantities of sugar contained in the volume, V, of these liquids will be represented by the products $\epsilon\frac{\alpha'}{\alpha}$, $\epsilon\frac{\alpha''}{\alpha}$, $\epsilon\frac{\alpha'''}{\alpha}$, &c., respectively. If the sugar examined, instead of being pure, is mixed with other but inactive substances, it is evident that these same products express the absolute weights of pure sugar contained in the weights of substances employed in the formation of the liquids of the given volume, V. It is possible to employ proof-tubes of different lengths; but it is then necessary to reduce by calculation the observed deflections to those which would have been produced in the same tube.

It often happens that solutions of sugar which have to be examined are turbid or strongly coloured. When this interferes with the examination, they must be clarified and rendered either quite colourless, or when this is not possible the colour must be at least reduced. This is often effected by precipitating the colouring-matter of the syrups with subacetate of lead; but the most accurate method is by a filter of animal-charcoal. The filtrates are then examined. When syrups contain, besides cane-sugar, other constituents which exert an action upon the plane of polarisation, the amount of cane-sugar present may be determined by inverting, by means of hydrochloric acid, the rotatory power of the cane-sugar. No other saccharine substance is, in fact, known which suffers a similar change under the same circumstances.

If, for instance, the liquid under examination contains besides cane-sugar, glucose, whose rotatory action on the plane of polarisation is in the same direction as that of cane-sugar; if α' be the deviation observed to be produced by the liquid, then α' is evidently the sum of the separate deflections of the cane-sugar x, and of the glucose, y. About one-tenth of its volume of hydrochloric acid is added to the syrup, and it is kept for ten minutes at a temperature of 140°—154°. The cane-sugar is thereby completely transformed into noncrystallisable sugar, which turns the plane of polarisation to the left, while the rotatory power of the glucose undergoes no alteration. When this change has been effected, the new deviation, α'', of the liquid is observed. It is now the difference between the deviation y, of the glucose and that of the noncrystallisable sugar derived from the cane-sugars. But the degree of dilution of the liquid having been changed by the addition of the hydrochloric acid, the deviation observed α'', must be replaced by the deviation, $\frac{10}{9}\ \alpha''$, which would have been observed if the inversion could have been produced without the addition of hydrochloric acid. Admitting therefore that a quantity of cane-sugar which effects a deviation, x, gives rise to a quantity of noncrystallisable sugar which effects a deviation, $r\ x$, we have—

$$\text{Before the inversion, } x+y=\alpha'.$$

$$\text{After the inversion, } y+r\ x=\frac{10}{9}\ \alpha''.$$

From these two equations the quantities x and y may be determined. The coefficient of inversion, r, is determined once for all by a special experiment performed upon pure cane-sugar at the temperature at which the experiments have afterwards to be made. According to Biot, this coefficient is 0·038 for hydrochloric acid at a temperature of 71·6°.

The process is the same when the cane-sugar is mixed with noncrystallisable sugar, turning the plane of polarisation to the left. In this case the initial deviation α', of the liquid is the difference between the deviation to the right r, of the cane-sugar, and the deviation z, to the left of the noncrystallisable sugar. After treating with hydrochloric acid, the deviation, α'', is composed of the deviations of the original noncrystallisable sugar, and of that produced by the action of the hydrochloric acid. We then have—

$$\text{Before the inversion, } x-z=\alpha'.$$

$$\text{After the inversion, } z+r\ x=\frac{10}{9}\ \alpha''.$$

It is important in examining optically noncrystallisable sugar always to employ the same temperature, because a change of temperature materially affects the rotatory power of this kind of sugar.

The Table appended on the following pages includes each degree of temperature from + 10 to + 35 Centigrade, and for qualities increasing in hundredths, this range being found sufficient for all practical purposes either in Europe or the Colonies.

To note the temperature at which the observation is made, a tube *z z*, *fig.* 1919, provided with a vertical branch, is employed. In this branch a thermometer, *t*, is placed.

The following are two examples of the use of the Table:—

1. A solution of a saccharine substance prepared in the normal proportions of weight and volume recommended, and giving before acidulation a notation on the left-hand part of the scale of	75 divisions.
And after the inversion (the temperature being + 15°) a notation in the opposite direction of	20 divisions.
Sum of the inversions	95 divisions.
2. Another liquor similarly prepared, giving before the inversion a notation on the left of	80 divisions.
And after the inversion, at the temperature of + 20°, another notation of the same direction, but only of	26 divisions.
Difference expressing the value of the inversion .	54 divisions.

The strength of the two solutions will be found thus: for the first, by seeing what is the figure of the column representing 15°, which is the nearest to the sum of the inversion, 65 divisions: it will be observed that this figure is 95·5, and that it corresponds to quality 70, shown on the same horizontal line in the last column but one, A; hence we conclude that the substance contained 70 per cent. of sugar.

As to the second solution, the figure nearest 54 is 53·6, in the column for the temperature of + 20°, and the strength sought will be 40 per cent. on the same line in the column of qualities. Finally, we shall find, besides, in the last column, B, of the table, the quantity in grammes and centigrammes of the sugar contained per litre in the solution, which is 114 grs. 45 cgrs. for the first, and 65 grs. 40 cgrs. for the second.

Other methods for the estimation of sugar have been adopted. We have already described Peligot's method by means of lime. When sugar is formed from starch, its complete saccharification may be determined by the action of sulphuric acid, for if on a strong solution of imperfectly-formed grape-sugar, nearly boiling hot, one drop of strong sulphuric acid be added, no perceptible change will ensue, but if the acid be dropped into solutions of either cane- or perfectly-formed grape-sugar, black carbonaceous particles will make their appearance.

TABLE FOR THE ANALYSIS OF SACCHARINE SUBSTANCES.

NOTE.—For liquids not submitted to acidulation the last two columns constitute a special table; in which case the figures in column A represent the number of degrees found, and those of column B the weight in grammes and centigrammes of sugar contained in a litre of liquid.

The numbers furnished by an analysis of solid sugars are necessarily comprised in the first hundred lines of the table; the thirty following lines have been added for the analysis of the principal natural saccharine fluids of high density. If liquors of a still greater density are presented, they will be comprised within the table by diluting them with a known quantity of water.

SUMS OR DIFFERENCES OF THE DIRECT AND INVERSE NOTATIONS, THE LATTER BEING DETERMINED AT A TEMPERATURE (CENTIGRADE) OF																										DEGREES	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	by wt. A	by vol. B
1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1	1,65
2,8	2,8	2,8	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,5	2,5	2,5	2	3,27
4,2	4,1	4,1	4,1	4,1	4,1	4,1	4,1	4,0	4,0	4,0	4,0	4,0	4,0	4,0	3,9	3,9	3,9	3,9	3,9	3,9	3,8	3,8	8,8	3,8	3,8	3	4,90
5,6	5,5	5,5	5,5	5,5	5,5	5,4	5,4	5,4	5,4	5,4	5,3	5,3	5,3	5,3	5,3	5,2	5,2	5,2	5,2	5,2	5,1	5,1	5,1	5,1	5,1	4	6,54
6,9	6,9	6,9	6,9	6,8	6,8	6,8	6,8	6,7	6,7	6,7	6,7	6,6	6,6	6,6	6,6	6,5	6,5	6,5	6,5	6,4	6,4	6,4	6,4	6,3	6,3	5	8,17
8,3	8,3	8,3	8,2	8,2	8,2	8,2	8,1	8,1	8,1	8,0	8,0	8,0	7,9	7,9	7,9	7,9	7,8	7,8	7,8	7,7	7,7	7,7	7,7	7,6	7,6	6	9,81
9,7	9,7	9,7	9,6	9,6	9,5	9,5	9,5	9,4	9,4	9,4	9,3	9,3	9,3	9,2	9,2	9,2	9,1	9,1	9,1	9,0	9,0	9,0	8,9	8,9	8,8	7	11,44
11,1	11,1	11,0	11,0	11,0	10,9	10,9	10,8	10,8	10,8	10,7	10,7	10,6	10,6	10,6	10,5	10,5	10,4	10,4	10,4	10,3	10,3	10,2	10,2	10,2	10,1	8	13,08
12,5	12,5	12,4	12,4	12,3	12,3	12,2	12,2	12,1	12,1	12,1	12,0	12,0	11,9	11,9	11,8	11,8	11,7	11,7	11,6	11,6	11,6	11,5	11,5	11,4	11,4	9	14,71
13,9	13,8	13,8	13,7	13,7	13,6	13,6	13,5	13,5	13,4	13,4	13,3	13,3	13,2	13,2	13,1	13,1	13,0	13,0	12,9	12,9	12,8	12,8	12,7	12,7	12,6	10	16,35
15,3	15,2	15,2	15,1	15,1	15,0	15,0	14,9	14,8	14,8	14,7	14,7	14,6	14,6	14,5	14,5	14 4	14,3	14,3	14,2	14,2	14,1	14,1	14,0	14,0	13,9	11	17,98
16,7	16,6	16,6	16,5	16,4	16,4	16,3	16,3	16,2	16,1	16,1	16,0	16,0	15,9	15,8	15,8	15,7	15,7	15,6	15,5	15,5	15,4	15,4	15,3	15,2	15,2	12	19,62
18,1	18,0	17,9	17,9	17,8	17,7	17,7	17,6	17,5	17,5	17,4	17,3	17,3	17,2	17,2	17,1	17,0	17,0	16,9	16,8	16,8	16,7	16,6	16,6	16,5	16,4	13	21,25
19,5	19,4	19,3	19,2	19,2	19,1	19,0	19,0	18,9	18,8	18,8	18,7	18,6	18,5	18,5	18,4	18,3	18,3	18,2	18,1	18,1	18,0	17,9	17,8	17,8	17,7	14	22,89
20,8	20,8	20,7	20,6	20,5	20,5	20,4	20,3	20,2	20,2	20,1	20,0	19,9	19,9	19,8	19,7	19,6	19,6	19,5	19,4	19,3	19,3	19,2	19,1	19,0	19,0	15	24,52
22,2	22,2	22,1	22,0	21,9	21,8	21,8	21,7	21,6	21,5	21,4	21,4	21,3	21,2	21,1	21,0	21,0	20,9	20,8	20,7	20,6	20,6	20,5	20,4	20,3	20,2	16	26,16
23,6	23,5	23,5	23,4	23,3	23,2	23,1	23,0	22,9	22,9	22,8	22,7	22,6	22,5	22,4	22,3	22,3	22,2	22,1	22,0	21,9	21,8	21,7	21,7	21,6	21,5	17	27,79
25,0	24,9	24,8	24,7	24,7	24,6	24,5	24,4	24,3	24,2	24,1	24,0	23,9	23,8	23,8	23,7	23,6	23,5	23,4	23,3	23,2	23,1	23,0	22,9	22,9	22,8	18	29,43
26,4	26,3	26,2	26,1	26,0	25,9	25,8	25,7	25,6	25,5	25,5	25,4	25,3	25,2	25,1	25,0	24,9	24,8	24,7	24,6	24,5	24,4	24,3	24,2	24,1	24,0	19	31,06
27,8	27,7	27,6	27,5	27,4	27,3	27,2	27,1	27,0	26,9	26,8	26,7	26,6	26,5	26,4	26,3	26,2	26,1	26,0	26,9	25,8	25,7	25,6	25,5	25,4	25,3	20	32,70
29,2	29,1	29,0	28,9	28,8	28,7	28,6	28,4	28,3	28,2	28,1	28,0	27,9	27,8	27,7	27,6	27,5	27,4	27,3	27,2	27,1	27,0	26,9	26,8	26,7	26,6	21	34,33
30,6	30,5	30,4	30,2	30,1	30,0	29,9	29,8	29,7	29,6	29,5	29,4	29,3	29,1	29,0	28,9	28,8	28,7	28,6	28,5	28,4	28,3	28,2	28,0	27,9	27,8	22	35,97
32,0	31,8	31,7	31,6	31,5	31,4	31,3	31,2	31,0	30,9	30,8	30,7	30,6	30,5	30,4	30,2	30,1	30,0	29,9	29,8	29,7	29,5	29,4	29,3	29,2	29,1	23	37,60
33,4	33,2	33,1	33,0	32,9	32,8	32,6	32,5	32,4	32,3	32,2	32,0	31,9	31,8	31,7	31,6	31,4	31,3	31,2	31,1	30,9	30,8	30,7	30,6	30,5	30,4	24	39,24
34,7	34,6	34,5	34,4	34,2	34,1	34,0	33,9	33,7	33,6	33,5	33,4	33,2	32,1	33,0	32,9	32,7	32,6	32,5	32,4	32,2	32,1	32,0	31,9	31,7	31,6	25	40,87
36,1	36,0	35,9	35,7	35,6	35,5	35,4	35,2	35,1	35,0	34,8	34,7	34,6	34,4	34,3	34,2	34,1	33,9	33,8	33,7	33,5	33,4	33,3	33,1	33,0	32,9	26	42,51
37,5	37,4	37,3	37,1	37,0	36,8	36,7	36,6	36,4	36,3	36,2	36,1	35,9	35,8	35,6	35,5	35,4	35,2	35,1	35,0	34,8	34,7	34,6	34,4	34,3	34,1	27	44,14
38,9	38,8	38,6	38,5	38,4	38,2	38,1	37,9	37,8	37,7	37,5	37,4	37,2	37,1	37,0	36,8	36,7	36,5	36,4	36,3	36,1	36,0	35,8	35,7	35,6	35,4	28	45,78
40,3	40,2	40,0	39,9	39,7	39,6	39,4	39,3	39,1	39,0	38,9	38,7	38,6	38,4	38,3	38,1	38,0	37,8	37,7	37,3	37,4	37,3	37,1	37,0	36,8	36,7	29	47,41
41,7	41,5	41,4	41,2	41,1	40,9	40,8	40,6	40,5	40,3	40,2	40,0	39,9	39,7	39,6	39,4	39,3	39,1	39,0	38,8	38'7	38,5	38,4	38,2	38,1	37,9	30	49,05
43,1	42,9	42,8	42,6	42,5	42,3	42,2	42,0	41,8	41,7	41,5	41,4	41,2	41,1	40,9	40,8	40,6	40,4	40,3	40,1	39,9	39,8	39,7	39,5	39,4	39,2	31	50,68
44,5	44,3	44,2	44,0	43,8	43,7	43,5	43,4	43,2	43,0	42,9	42,7	42,6	42,4	42,2	42,1	41,9	41,8	41,6	41,4	41,3	41,1	41,0	40,8	40,6	40,5	32	52,32
45,9	45,7	45,5	45,4	45,2	45,0	44,9	44,7	44,5	44,4	44,2	44,0	43,9	43,7	43,6	43,4	43,2	43,1	42,9	42,7	42,6	42,4	42,2	42,1	41,9	41,7	33	53,95
47,3	47,1	46,9	46,7	46,6	46,4	46,2	46,1	45,9	45,7	45,6	45,4	45,2	45,0	44,9	44,7	44,5	44,4	44,2	44,0	43,9	43,7	43,5	43,3	43,2	43,0	34	55,59
48,6	48,5	48,3	48,1	47,9	47,8	47,6	47,4	47,2	47,1	46,9	46,7	46,5	46,5	46,2	46,0	45,8	45,7	45,5	45,3	45,1	45,0	44,8	44,6	44,4	44,3	35	57,22
50,0	49,9	49,7	49,5	49,3	49,1	49,0	48,8	48,6	48,4	48,2	48,1	47,9	47,7	47,5	47,3	47,2	47,0	46,8	46,6	46,4	46,3	46,1	45,9	45,7	45,6	36	58,86
51,4	51,2	51,1	50,9	50,7	50,5	50,3	50,1	49,9	49,9	49,6	49,4	49,2	49,0	48,8	48,6	48,5	48,3	48,1	47,9	47,7	47,5	47,4	47,2	47,0	46,8	37	60.49
52,8	52,6	52,4	52,2	52,1	51,9	51,7	51,5	51,3	51,1	50,9	50,7	50,5	50,3	50,2	50,0	49,8	49,6	49,4	49,2	49,0	48,8	48,7	48,4	48,3	48,1	38	62,13

SUMS OR DIFFERENCES OF THE DIRECT AND INVERSE NOTATIONS, THE LATTER BEING DETERMINED AT A TEMPERATURE (CENTIGRADE) OF																										DEGREES	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	by wt. A	by vol. B
54,2	54,0	53,8	53,6	53,4	53,2	53,0	52,8	52,6	52,4	52,3	52,1	51,9	51,7	51,5	51,3	51,1	50,9	50,7	50,5	50,3	50,1	49,9	49,7	49,5	49,3	39	63,76
55,6	55,4	55,2	55,0	54,8	54,6	54,4	54,2	54,0	53,8	53,6	53,4	53,2	53,0	52,8	52,6	52,4	52,2	52,0	51,8	51,6	51,4	51,2	51,0	50,8	50,6	40	65,40
57,0	56,8	56,6	56,4	56,2	56,0	55,8	55,5	55,3	55,1	54,9	54,7	54,5	54,3	54,1	53,9	53,7	53,5	53,3	53,1	52,9	52,7	52,5	52,3	52,1	51,9	41	67,03
58,4	58,2	58,0	57,7	57,5	57,3	57,1	56,9	56,7	56,5	56,3	56,1	55,9	55,6	55,4	55,2	55,0	54,8	54,6	54,4	54,2	54,0	53,8	53,5	53,3	53,1	42	68,67
59,8	59,5	59,3	59,1	58,9	58,7	58,5	58,3	58,0	57,8	57,6	57,4	57,2	57,0	56,8	56,5	56,3	56,1	55,9	55,7	55,5	55,2	55,0	54,8	54,6	54,4	43	70,30
61,2	60,9	60,7	60,5	60,3	60,1	59,8	59,6	59,4	59,2	59,0	58,7	58,5	58,3	58,1	57,9	57,6	57,4	57,2	57,0	56,8	56,5	56,3	56,1	55,9	55,7	44	71,94
62,5	62,3	62,1	61,9	61,6	61,4	61,2	61,0	60,7	60,5	60,3	60,1	59,8	59,6	59,4	59,2	58,9	58,7	58,5	58,3	58,0	57,8	57,6	57,4	57,1	56,9	45	73,57
63,9	63,7	63,5	63,2	63,0	62,8	62,6	62,3	62,1	61,9	61,6	61,4	61,2	60,9	60,7	60,5	60,3	60,0	59,8	59,6	59,3	59,1	58,9	58,6	58,4	58,2	46	75,21
65,3	65,1	64,9	64,6	64,4	64,1	63,9	63,7	63,4	63,2	63,0	62,7	62,5	62,3	62,0	61,8	61,6	61,3	61,1	60,9	60,6	60,4	60,2	59,9	59,7	59,4	47	76,84
66,7	66,5	66,2	66,0	65,8	65,5	65,3	65,0	64,8	64,6	64,3	64,1	63,8	63,6	63,4	63,1	62,9	62,6	62,4	62,2	61,9	61,7	61,4	61,2	61,0	60,7	48	78,48
68,1	67,9	67,6	67,4	67,1	66,9	66,6	66,4	66,1	65,9	65,7	65,4	65,2	64,9	64,7	64,4	64,2	63,9	63,7	63,4	63,2	63,0	62,7	62,5	62,2	62,0	49	80,11
69,5	69,2	69,0	68,7	68,5	68,2	68,0	67,7	67,5	67,2	67,0	66,7	66,5	66,2	66,0	65,7	65,5	65,2	65,0	64,7	64,5	64,2	64,0	63,7	63,5	63,2	50	81,75
70,9	70,6	70,4	70,1	69,9	69,6	69,4	69,1	68,8	68,6	68,3	68,1	67,8	67,6	67,3	67,1	66,8	66,5	66,3	66,0	65,8	65,5	65,3	65,0	64,8	64,5	51	83,38
72,3	72,0	71,8	71,5	71,2	71,0	70,7	70,5	70,2	69,9	69,7	69,4	69,2	68,9	68,6	68,4	68,1	67,9	67,6	67,5	67,1	66,8	66,6	66,3	66,0	65,8	52	85,02
73,7	73,4	73,1	72,9	72,6	72,3	72,1	71,8	71,5	71,3	71,0	70,7	70,5	70,2	70,0	69,7	69,4	69,2	68,9	68,6	68,4	68,1	67,8	67,6	67,3	67,0	53	86,65
75,1	74,8	74,5	74,2	74,0	73,7	73,4	73,2	72,9	72,6	72,4	72,1	71,8	71,5	71,3	71,0	70,7	70,5	70,2	69,9	69,7	69,4	69,1	68,8	68,6	68,3	54	88,29
76,4	76,2	75,9	75,6	75,3	75,1	74,8	74,5	74,2	74,0	73,7	73,4	73,1	72,9	72,6	72,3	72,0	71,8	71,5	71,2	70,9	70,7	70,4	70,1	69,8	69,6	55	89,92
77,8	77,6	77,3	77,0	76,7	76,4	76,2	75,9	75,6	75,3	75,0	74,8	74,5	74,2	73,9	73,6	73,4	73,1	72,8	72,5	72,2	72,0	71,7	71,4	71,1	70,8	56	91,56
79,2	79,0	78,7	78,4	78,1	77,8	77,5	77,2	76,9	76,7	76,4	76,1	75,8	75,5	75,2	74,9	74,7	74,4	74,1	73,8	73,5	73,2	73,0	72,7	72,4	72,1	57	93,19
80,6	80,3	80,0	79,7	79,5	79,2	78,9	78,6	78,3	78,0	77,7	77,4	77,1	76,8	76,6	76,3	76,0	75,7	75,4	75,1	74,8	74,5	74,2	73,9	73,7	73,4	58	94,83
82,0	81,7	81,4	81,1	80,8	80,5	80,2	79,9	79,6	79,3	79,1	78,8	78,5	78,2	77,9	77,6	77,3	77,0	76,7	76,4	76,1	75,8	75,5	75,2	74,9	74,6	59	96,46
83,4	83,1	82,8	82,5	82,2	81,9	81,6	81,3	81,0	80,7	80,4	80,1	79,8	79,5	79,2	78,9	78,6	78,3	78,0	77,7	77,4	77,1	76,8	76,5	76,2	75,9	60	98,10
84,8	84,5	84,2	83,9	83,6	83,3	83,0	82,6	82,3	82,0	81,7	81,4	81,1	80,8	80,5	80,2	79,9	79,6	79,3	79,0	78,7	78,4	78,1	77,8	77,5	77,2	61	99,73
86,2	85,9	85,6	85,2	84,9	84,6	84,3	84,0	83,7	83,4	83,1	82,8	82,5	82,1	81,8	81,5	81,2	80,9	80,6	80,3	80,0	79,7	79,4	79,0	78,7	78,4	62	101,37
87,6	87,2	86,9	86,5	86,3	86,0	85,7	85,4	85,0	84,7	84,4	84,1	83,8	83,5	83,2	82,8	82,5	82,2	81,9	81,6	81,3	80,9	80,6	80,3	80,0	79,7	63	103,00
89,0	88,6	88,3	88,0	87,7	87,4	87,0	86,7	86,4	86,1	85,8	85,4	85,1	84,8	84,5	84,2	83,8	83,5	83,2	82,9	82,6	82,2	81,9	81,6	81,3	81,0	64	104,64
90,3	90,0	89,7	89,4	89,0	88,7	88,4	88,1	87,7	87,4	87,1	86,8	86,4	86,1	85,8	85,5	85,1	84,8	84,5	84,2	83,8	83,5	83,2	82,9	82,5	82,2	65	106,27
91,7	91,4	91,1	90,7	90,4	90,1	89,8	89,4	89,1	88,8	88,4	88,1	87,8	87,4	87,1	86,8	86,5	86,1	85,8	85,5	85,1	84,8	84,5	84,1	83,8	83,5	66	107,91
93,1	92,8	92,5	92,1	91,8	91,4	91,1	90,8	90,4	90,1	89,8	89,4	89,1	88,8	88,4	88,1	87,8	87,4	87,1	86,8	86,4	86,1	85,8	85,4	85,1	84,8	67	109,54
94,5	94,2	93,8	93,5	93,2	92,8	92,5	92,1	91,8	91,5	91,1	90,8	90,4	90,1	89,8	89,4	89,1	88,7	88,4	88,1	87,7	87,4	87,0	86,7	86,4	86,0	68	118,18
95,9	95,6	95,2	94,9	94,5	94,1	93,8	93,5	93,1	92,8	92,5	92,1	91,8	91,4	91,1	90,7	90,4	90,0	89,7	89,3	89,0	88,7	88,3	88,0	87,6	87,3	69	112,81
97,3	96,9	96,6	96,2	95,9	95,5	95,2	94,8	94,5	94,1	93,8	93,4	93,1	92,7	92,4	92,0	91,7	91,3	91,0	90,6	90,3	89,9	89,6	89,2	88,9	88,5	70	114,45
98,7	98,3	98,0	97,6	97,3	96,9	96,6	96,2	95,8	95,5	95,1	94,8	94,4	94,1	93,7	93,4	93,0	92,6	92,3	91,9	91,6	91,2	90,2	90,5	90,2	89,8	71	116,08
100,1	99,7	99,4	99,0	98,6	98,3	97,9	97,6	97,2	96,8	96,5	96,1	95,8	95,4	95,0	94,7	94,3	94,0	93,6	93,2	92,9	92,5	92,2	91,8	91,4	91,1	72	117,72
101,5	101,1	100,7	100,4	100,0	99,6	99,3	98,9	98,5	98,2	97,8	97,4	97,1	96,7	96,4	96,0	95,6	95,3	94,9	94,5	94,2	93,8	93,4	93,1	92,7	92,3	73	119,35
102,9	102,5	102,1	101,7	101,4	101,0	100,6	100,3	99,9	99,5	99,2	98,8	98,4	98,0	97,7	97,3	96,9	96,6	96,2	95,8	95,5	95,1	94,7	94,3	94,0	93,6	74	120,99
104,2	103,9	103,5	103,1	102,7	102,4	102,0	101,6	101,2	100,9	100,5	100,1	99,7	99,4	99,0	98,6	98,2	97,9	97,5	97,1	96,7	96,4	96,0	95,6	95,2	94,9	75	122,62
105,6	105,3	104,9	104,5	104,1	103,7	103,4	103,0	102,6	102,2	101,8	101,5	101,1	100,7	100,3	99,9	99,6	99,2	98,8	98,4	98,0	97,7	97,3	96,9	96,5	96,1	76	124,26
107,0	106,6	106,3	105,9	105,5	105,1	104,7	104,3	103,9	103,6	103,2	102,8	102,4	102,0	101,6	101,2	100,9	100,5	100,1	99,7	99,3	98,9	98,6	98,2	97,8	97,4	77	125,89
108,4	108,0	107,6	107,2	106,9	106,5	106,1	105,7	105,3	104,9	104,5	104,1	103,7	103,3	103,0	102,6	102,2	101,8	101,4	101,0	100,6	100,2	99,8	99,4	99,1	98,7	78	127,53
109,8	109,4	109,0	108,6	108,2	107,8	107,4	107,0	106,6	106,2	105,9	105,5	105,1	104,7	104,3	103,9	103,5	103,1	102,7	102,3	101,9	101,5	101,1	100,7	100,3	99,9	79	129,16
111,2	110,8	110,4	110,0	109,6	109,2	108,8	108,4	108,0	107,6	107,2	106,8	106,4	106,0	105,6	105,2	104,8	104,4	104,0	103,6	103,2	102,8	102,4	102,0	101,6	101,2	80	130,80
112,6	112,2	111,8	111,4	111,0	110,6	110,2	109,7	109,3	108,9	108,5	108,1	107,7	107,3	106,9	106,5	106,1	105,7	105,3	104,9	104,6	104,1	103,7	102,2	102,9	102,5	81	132,43
114,0	113,6	113,2	112,7	112,3	111,9	111,5	111,1	110,7	110,3	109,9	109,5	109,1	108,6	108,2	107,8	107,4	107,0	106,6	106,2	105,9	105,4	105,0	104,5	104,1	103,7	82	134,07
115,4	114,9	114,5	114,1	113,7	113,3	112,9	112,5	112,0	111,6	111,2	110,8	110,4	110,0	109,6	109,1	108,7	108,3	107,9	107,5	107,2	106,6	106,2	105,8	105,4	105,0	83	135,70
116,8	116,3	115,9	115,5	115,1	114,7	114,2	113,8	113,4	113,0	112,6	112,1	111,7	111,3	110,9	110,5	110,0	109,6	109,2	108,8	108,5	107,9	107,5	107,1	106,7	106,3	84	137,34

SUMS OR DIFFERENCES OF THE DIRECT AND INVERSE NOTATIONS, THE LATTER BEING DETERMINED AT A TEMPERATURE (CENTIGRADE) OF																										DEGREES	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	by wt. A	by vol. B
118,1	117,7	117,3	116,9	116,4	116,0	115,6	115,2	114,7	114,3	113,9	113,5	113,0	112,6	112,2	111,8	111,3	110,9	110,5	110,1	109,7	109,2	108,8	108,4	107,9	107,5	85	138,97
119,5	119,1	118,7	118,2	117,8	117,4	117,0	116,5	116,1	115,7	115,2	114,8	114,4	113,9	113,5	113,1	112,7	112,2	111,8	111,4	111,0	110,5	110,1	109,6	109,2	108,8	86	140,61
120,9	120,5	120,1	119,6	119,2	118,7	118,3	117,9	117,4	117,0	116,6	116,1	115,7	115,3	114,8	114,4	114,0	113,5	113,1	112,7	112,3	111,8	111,4	110,9	110,5	110,0	87	142,24
122,3	121,9	121,4	121,0	120,6	120,1	119,7	119,2	118,8	118,4	117,9	117,5	117,0	116,6	116,2	115,7	115,3	114,8	114,4	114,0	113,6	113,1	112,6	112,2	111,8	111,3	88	143,88
123,7	123,2	122,8	122,4	121,9	121,5	121,0	120,6	120,1	119,7	119,3	118,8	118,4	117,9	117,5	117,0	116,6	116,1	115,7	115,2	114,9	114,4	113,9	113,5	113,0	112,6	89	145,51
125,1	124,6	124,2	123,7	123,3	122,8	122,4	121,9	121,5	121,0	120,6	120,1	119,7	119,2	118,8	118,3	117,9	117,4	117,0	116,5	116,2	115,6	115,2	114,7	114,3	113,9	90	147,15
126,5	126,0	125,6	125,1	124,7	124,2	123,8	123,3	122,8	122,4	121,9	121,5	121,0	120,6	120,1	119,7	119,2	118,7	118,3	117,8	117,5	116,9	116,5	116,0	115,6	115,1	91	148,78
127,9	127,4	127,0	126,5	126,0	125,6	125,1	124,7	124,2	123,7	123,3	122,8	122,4	121,9	121,4	121,0	120,5	120,1	119,6	119,1	118,8	118,2	117,8	117,3	116,8	116,4	92	150,42
129,3	128,8	128,3	127,9	127,4	126,9	126,5	126,0	125,5	125,1	124,6	124,1	123,7	123,2	122,8	122,3	121,8	121,4	120,9	120,4	120,1	119,5	119,0	118,6	117,1	117,6	93	152,05
130,7	130,2	129,7	129,2	128,8	128,3	127,8	127,4	126,9	126,4	126,0	125,5	125,0	124,5	124,1	123,6	123,1	122,7	122,2	121,7	121,4	120,8	120,3	119,8	119,4	118,9	94	153,69
132,0	131,6	131,1	130,6	130,1	129,7	129,2	128,7	128,2	127,8	127,3	126,8	126,3	125,9	125,4	124,9	124,4	124,0	123,5	123,0	122,6	122,1	121,6	121,1	120,6	120,2	95	155,32
133,4	133,0	132,5	132,0	131,5	131,0	130,6	130,1	129,6	129,1	128,6	128,2	127,7	127,2	126,7	126,2	125,8	125,3	124,8	124,3	123,9	123,4	122,9	122,4	121,9	121,4	96	156,96
134,8	134,3	133,9	133,4	132,9	132,4	131,9	131,4	130,9	130,5	130,0	129,5	129,0	128,5	128,0	127,5	127,1	126,6	126,1	125,6	125,2	124,6	124,2	123,7	123,2	122,7	97	158,59
136,2	135,7	135,2	134,7	134,3	133,8	133,3	132,8	132,3	131,8	131,3	130,8	130,3	129,8	129,4	128,9	128,4	127,9	127,4	126,9	126,5	125,9	125,4	124,9	124,5	124,0	98	160,23
137,6	137,1	136,6	136,1	135,6	135,1	134,6	134,1	133,6	133,1	132,7	132,2	131,7	131,2	130,7	130,2	129,7	129,2	128,7	128,2	127,8	127,2	126,7	126,2	125,7	125,2	99	161,86
139,0	138,5	138,0	137,5	137,0	136,5	136,0	135,5	135,0	134,5	134,0	133,5	133,0	132,5	132,0	131,5	131,0	130,5	130,0	129,5	129,0	128,5	128,0	127,5	127,0	126,5	100	163,50
140,4	139,9	139,4	138,9	138,4	137,9	137,4	136,8	136,3	135,8	135,3	134,8	134,3	133,8	133,3	132,8	132,3	131,8	131,3	130,8	130,3	129,8	129,3	128,8	128,3	127,8	101	165,15
141,8	141,3	140,8	140,2	139,7	139,2	138,7	138,2	137,7	137,2	136,7	136,2	135,7	135,1	134,6	134,1	133,6	133,1	132,6	132,1	131,6	131,1	130,6	130,0	129,5	129,0	102	166,77
143,2	142,6	142,1	141,6	141,1	140,6	140,1	139,6	139,0	138,5	138,0	137,5	137,0	136,5	136,0	135,4	134,9	134,4	133,9	133,4	132,9	132,4	131,8	131,3	130,8	130,3	103	168,40
144,6	144,0	143,5	143,0	142,5	142,0	141,4	140,9	140,4	139,9	139,4	138,8	138,3	137,8	137,3	136,8	136,2	135,7	135,2	134,7	134,2	133,6	133,1	132,6	132,1	131,6	104	170,04
145,9	145,4	144,9	144,4	143,8	143,3	142,8	142,3	141,7	141,2	140,7	140,2	139,6	139,1	138,6	138,1	137,5	137,0	136,5	136,0	135,4	134,9	134,5	133,9	133,3	132,8	105	171,67
147,3	146,8	146,3	145,7	145,2	144,7	144,2	143,6	143,1	142,6	142,0	141,5	141,0	140,5	139,9	139,4	138,9	138,3	137,8	137,3	136,7	136,2	135,7	135,1	134,6	134,1	106	173,31
148,7	148,2	147,7	147,1	149,6	146,0	145,5	145,0	144,5	143,9	143,4	142,8	142,3	141,8	141,2	140,7	140,2	139,6	139,1	138,6	138,0	137,5	137,0	136,4	135,9	135,3	107	174,94
150,1	149,6	14,90	148,5	148,0	147,4	146,9	146,3	145,8	145,3	144,7	144,2	143,6	143,1	142,6	142,0	141,5	140,9	140,4	139,9	139,3	138,8	138,2	137,7	137,2	136,6	108	176,58
151,5	151,0	150,4	149,9	149,3	148,1	148,2	147,7	147,1	146,6	146,1	145,5	145,0	144,4	143,9	143,3	142,8	142,2	141,7	141,1	140,6	140,1	139,5	139,0	138,4	137,9	109	178,21
152,9	152,3	151,8	151,2	150,7	150,1	149,6	149,0	148,5	147,9	147,4	146,8	146,3	145,7	145,2	144,6	144,1	143,5	143,0	142,4	141,0	141,3	140,8	140,2	139,7	139,1	110	179,85
54,3	153,7	153,2	152,6	152,1	151,5	151,0	150,4	149,8	149,3	148,7	148,2	147,6	147,1	146,5	146,0	145,4	144,8	144,3	143,7	143,2	142,6	142,1	141,5	141,0	140,4	111	181,48
55,7	155,1	154,6	154,0	153,4	152,9	152,3	151,8	151,2	150,6	150,1	149,5	149,0	148,4	147,8	147,3	146,7	146,2	145,6	145,0	144,5	143,9	843,4	142,8	142,2	141,7	112	183,12
157,1	156,5	155,9	155,4	154,8	154,2	153,7	153,1	152,5	152,0	151,4	150,8	150,3	149,7	149,2	148,6	148,0	147,5	146,9	146,3	145,8	145,2	144,6	144,1	143,5	142,9	113	184,75
158,5	157,9	157,3	156,7	156,2	155,6	155,0	154,5	153,9	153,3	152,8	152,2	151,6	151,0	150,5	149,9	149,3	148,8	148,2	147,6	147,1	146,5	145,2	145,3	144,8	144,2	114	186,39
159,8	159,3	158,7	158,1	157,5	157,0	156,4	155,8	155,2	154,7	154,1	153,5	152,9	152,4	151,8	151,2	150,6	150,1	149,5	148,9	148,3	147,8	147,2	146,6	146,0	145,5	115	188,02
161,2	160,6	160,1	159,5	158,9	158,3	157,8	157,2	156,6	156,0	155,4	154,9	154,3	153,7	153,1	152,5	152,0	151,4	150,8	160,2	149,6	149,1	148,5	147,9	147,3	146,7	116	189,66
162,6	162,0	161,5	165,9	160,3	159,7	159,0	158,5	157,9	157,4	156,9	156,2	155,6	155,0	154,4	153,8	153,3	152,7	152,1	151,5	150,9	150,8	149,8	149,2	148,6	148,0	117	191,26
164,0	163,4	162,8	162,2	161,7	161,1	160,5	159,9	159,3	158,7	158,1	157,5	156,9	156,3	155,8	155,2	154,6	154,0	153,4	152,8	152,2	151,6	151,0	250,4	149,9	149,3	118	192,93
165,4	164,8	164,2	163,6	163,0	162,4	161,8	161,2	160,6	160,0	159,5	158,9	158,3	157,7	157,1	156,5	155,9	155,3	154,7	154,1	153,5	152,9	152,3	151,7	151,1	150,5	119	194,56
166,8	166,2	165,6	165,0	164,4	163,8	163,2	162,6	162,0	161,4	160,8	160 2	159,6	159,0	158,4	157,8	157,2	156,6	156,0	155,4	154,8	154,2	153,6	153,0	152,4	151,8	120	196,20
168,2	167,6	167,0	166,4	165,8	165,2	164,6	163,9	163,3	162,7	162,1	161,5	160,9	160,3	159,7	159,1	158,5	157,9	157,3	156,7	156,1	155,5	154,9	154,3	153,7	153,1	121	197,83
169,6	169,0	168,4	167,7	167,1	166,5	165,9	165,3	164,7	164,1	163,5	162,9	162,3	161,6	161,0	160,4	159,8	159,2	158,6	158,0	257,4	156,8	156,2	155,5	154,9	154,3	122	199,47
171,0	170,3	169,7	169,1	168,5	167,9	167,3	166,7	166,0	165,4	164,8	164,2	163,6	163,0	162,4	161,7	161,1	160,5	159,9	159,3	158,7	158,0	157,4	156,8	156,2	155,6	123	201,10
172,4	171,7	171,1	170,5	169,9	169,3	168,6	168,0	167,4	166,8	166,2	165,5	164,9	164,3	163,7	163,1	162,4	161,8	161,2	160,6	160,0	159,3	158,7	158,1	157,5	156,9	124	202,74
173,7	173,1	172,5	171,9	171,2	170,6	170,0	169,4	168,7	168,1	167,5	166,9	166,2	165,6	165,0	164,4	163,7	163,1	162,5	161,9	161,2	160,6	160,0	159,4	158,7	158,1	125	204,37
175,1	174,5	173,9	173,2	172,6	172,0	171,4	170,7	172,1	169,5	168,8	168,2	167,6	166,9	166,3	165,7	165,1	164,4	163,8	163,2	162,5	161,9	161,3	160,6	160,0	159,4	126	206,01
176,5	175,9	175,3	174,6	174,0	173,3	172,7	172,1	171,4	170,8	170,2	169,5	168,9	168,3	167,6	167,0	166,4	165,7	165,1	164,5	163,8	163,2	162,6	161,9	161,3	160,6	127	207,64
177,9	177,3	176,6	176,0	175,4	174,7	174,1	173,4	172,8	172,2	171,5	170,9	170,2	169,6	169,0	168,3	167,7	167,0	166,4	165,8	165,1	164,5	163,8	163,2	162,6	161,9	128	209,28
179,3	178,7	178,0	177,4	176,7	176,1	175,4	174,8	174,1	173,5	172,9	172,2	171,6	170,9	170,3	169,6	169,0	168,3	167,7	167,0	166,4	165,8	16,51	164,6	163,8	163,2	129	210,91
180,7	180,0	179,4	178,7	178,1	177,4	176,8	176,1	175,5	174,8	174,2	173,5	172,9	17[illegible],2	171,6	170,9	170,3	169,6	166,0	168,3	167,7	167,0	166,4	165,7	165,1	164,4	130	212,55

The black oxide of copper is not affected by being boiled in solution of starch-sugar.

'If a solution of grape-sugar,' says Trommer, 'and potash be treated with a solution of sulphate of copper, till the separated hydrate be re-dissolved, a precipitate of red oxide will soon take place, at common temperatures, but it immediately forms if the mixture is heated. A liquid containing $\frac{1}{100000}$ of grape-sugar, even one-millionth part,' says he, 'gives a perceptible tinge (orange), if the light is let fall upon it.' To obtain such an exact result, very great nicety must be used in the dose of alkali, which is found extremely difficult to hit. With a regulated alkaline mixture, however, an exceedingly small portion of starch-sugar, is readily detected, even when mixed with Muscovado sugar.

Fehling has reduced this to a quantitative test, and makes a solution of copper that will keep permanently. This is seen by the following:—

40 grammes of sulphate of copper,
160 grammes of neutral tartrate of potash, or 200 grammes of tartrate of soda, dissolved and added to
700—800 cub. c. (grammes of caustic soda, specific gravity 1·12).

This is diluted with water to 1154·5 cub. c.

Of this solution 1 cub. c. = 0·0050 grape-sugar, or
0·00475 cane-sugar.

Grains may be used instead of grammes, and then 1 grain = 0·0050 grape-sugar, without change of calculation.

$$\left.\begin{array}{l}\text{100 parts of grape-sugar} \quad . \quad . \quad . \\ \text{95} \quad ,, \quad \text{cane-sugar} \quad . \quad . \quad . \\ \text{90} \quad ,, \quad \text{starch} \quad . \quad . \quad . \quad . \end{array}\right\} = 220{\cdot}5\ CuO, \text{ or } 198\ Cu^2O.$$

Urine may be tested with this. It should be first diluted 10 to 20 times with water; when the test is added, it should be boiled a few seconds, when the suboxide of copper falls. Very constant results may be obtained.

Horsley detects minute quantities of sugar by means of chromate of potash.

Of the Sugar-cane, and the extraction of sugar from it.—Though we have no direct authority for believing that the sugar-*cane* was known to the ancients, we find scattered through their writings notices of the occasional use of sweet substances different from honey.

The writers alluded to are these: Theophrastus, Dioscorides, Galen, Strabo, and Pliny; some of them speak distinctly of canes and reeds. Humboldt, after the most elaborate historical and botanical researches in the New World, arrived at the conclusion that before America was discovered by the Spaniards the inhabitants of that continent and the adjacent islands were entirely unacquainted with the sugar-canes, with any of our corn-plants, and with rice, The progressive diffusion of the cane has been thus traced out by the partisans of its oriental origin. From the interior of Asia it was transplanted first into Cyprus, and thence into Sicily, or possibly by the Saracens directly into the latter island, in which a large quantity of sugar was manufactured in the year 1148. Lafitau relates the donation made by William II., King of Sicily, to the convent of St. Benoit, of a mill for crushing sugar-canes, along with all its privileges, workmen, and dependencies: which remarkable gift bears the date of 1166. According to this author, the sugar-cane must have been imported into Europe at the period of the Crusades. The monk Albertus Aquensis, in the description which he has given of the processes employed at Acre and at Tripoli to extract sugar, says that in the Holy Land the Christian soldiers, being short of provisions, had recourse to sugar-canes, which they chewed for subsistence. Towards the year 1420, Dom Henry, Regent of Portugal, caused the sugar-cane to be imported into Madeira from Sicily. This plant succeeded perfectly in Madeira and the Canaries; and until the discovery of America, these islands supplied Europe with the greater portion of the sugar which it consumed.

The cane is said by some to have passed from the Canaries into the Brazils; but by others, from the coast of Angola in Africa, where the Portuguese had a sugar colony. It was transported, in 1506, from the Brazils and the Canaries, into Hispaniola or Hayti, where several crushing-mills were constructed in a short time. It would appear, moreover, from the statement of Peter Martyr, in the third book of his first Decade, written during the second expedition of Christopher Columbus, which happened between 1493 and 1495, that even at this date the cultivation of the sugar-cane was widely spread in St. Domingo.

Sugar was first brought to England in 1563, by Admiral Hawkins, and a century later English planters were realising great wealth in Barbadoes.

It has been supposed to have been introduced into Hayti by Columbus himself, on his first voyage, along with other productions of Spain and the Canaries, and that therefore its cultivation had come into considerable activity at the period of his second expedition. Towards the middle of the seventeenth century, the sugar-cane was imported into Barbadoes from Brazil, then into the other English West Indian possessions, into the Spanish Islands on the coast of America, into Mexico, Peru, Chili, and, last of all, into the French, Dutch, and Danish colonies.

The sugar-cane, *Arundo saccharifera*, is a plant of the graminiferous family, which varies in height from 8 to 10 or even to 20 feet. Its diameter is about an inch and a half; its stem is dense, brittle, and of a green hue, which verges to yellow at the approach of maturity. It is divided by prominent annular joints of a whitish-yellow colour. These joints are placed about 3 inches apart; and send forth leaves, which fall off with the ripening of the plant. The leaves are 3 or 4 feet long, flat, straight, pointed, from 1 to 2 inches in breadth, of a sea-green tint, striated in their length, alternate, embracing the stem by their base. They are marked along their edges with almost imperceptible teeth. In the eleventh or twelfth month of their growth the canes push forth at their top a sprout 7 or 8 feet in height, nearly half an inch in diameter, smooth, and without joints, to which the name *arrow* is given. This is terminated by an ample panicle, about 2 feet long, divided into several knotty ramifications, composed of very numerous flowers, of a white colour, apetalous, and furnished with 3 stamens, the anthers of which are a little oblong. The roots of the sugar-cane are jointed and nearly cylindrical; in diameter they are about one-twelfth of an inch; in their utmost length 1 foot, presenting over their surface a few short radicles.

The stem of the cane in its ripe state is heavy, very smooth, brittle, of a yellowish-violet, reddish, or whitish colour, according to the variety. It is filled with a fibrous, spongy, dirty-white pith, which contains very abundant sweet juice. This juice is elaborated separately in each internodary portion, the functions of which are in this respect independent of the portions above and below. The cane is propagated by cuttings or joints of proper length, from 15 to 20 inches, in proportion to the nearness of the joints, which are generally taken from the tops of the canes, just below the leaves.

There are several *varieties of the sugar-cane*. The longest known is the *Creole*, or common sugar-cane, which was originally introduced at Madeira. It grows freely in every region within the tropics, on a moist soil, even at an elevation of 3,000 feet above the level of the sea. In Mexico, among the mountains of Caudina-Masca, it is cultivated to a height of more than 5,000 feet. The quantity and quality of sugar which it yields are proportional to the heat of the place where it grows, provided it be not too moist and marshy.

Another variety is the Otaheitan cane. It was introduced into the West Indies about the end of the eighteenth century. This variety, stronger, taller, with longer spaces between the joints, quicker in its growth, and much more productive in sugar, succeeds perfectly well in lands which seem too much impoverished to grow the ordinary cane. It sends forth shoots at temperatures which chill the growth and development of the creole plant. Its maturation does not take more than a year, and is accomplished sometimes in nine months. From the strength of its stem, and the woodiness of its fibres, it better resists the storms. It weighs a third more, affords a sixth more juice, and a fourth more sugar, than the common variety. It yields four crops in the same time that the creole cane yields only three. Its juice contains less feculency and mucilage, whence its sugar is more easily crystallised, and of a fairer colour.

Another variety, valuable chiefly from its hardiness, is the *purple violet* from Java. It grows from 8 to 10 feet high. This cane is covered with a resinous film, which is difficult to grind; but as the sugar yielded is of excellent quality, this variety is of considerable value in bordering cane-fields, protecting them from the inroads of cattle.

There is a caste in Ceylon, called *Jaggeraros*, who make sugar from the produce of the *Caryota urens*, or Kitul-tree; and the sugar is styled *Jaggery*. Sugar is not usually made in Ceylon from the sugar-cane; but either from the juice of the Kitul, from the *Cocos nucifera*, or the *Borassus flabelliformis* (the Palmyra Palm).

1921

Several sorts of cane are cultivated in India.

The *Cadjoolee* (*fig.* 1921) is a purple-coloured cane; yields a sweeter and richer juice than the yellow or light-coloured, but in less quantities, and is harder to press.

It grows in dry lands. When eaten raw, it is somewhat dry and pithy in the mouth, but is esteemed very good for making sugar. It is not known to the West India planter. The leaves rise from a point 6 feet above the ground. An oblique and transverse section of the cane is represented by the parts near the bottom of the figure.

The *Pooree* is a light-coloured cane, yellow, inclining to white, deeper yellow when ripe and on rich ground. West India planters consider it the same sort as one of theirs. It is softer and more juicy than the preceding, but the juice is less rich, and produces a weaker sugar. It requires seven parts of pooree-juice to make as much *goor* as is produced from six of the cadjoolee. Much of this cane is brought to the Calcutta market, and eaten raw.

The *Cullorah* thrives in swampy lands, is light coloured, and grows to a great height. Its juice is more watery, and yields a weaker sugar also than the cadjoolee.

The manufacture of sugar in Bengal is conducted by the natives in the most primitive manner possible; the poverty and ignorance of the ryots or peasants being serious obstacles to the introduction of any system different from that practised by their forefathers. Early in June the soil is brought into a soft muddy state; slips of the cane, with one or two joints, are planted in rows about 3½ feet apart, and 18 inches asunder in the rows; when about 3 inches above ground the earth is partially loosened, and in August trenches are cut, to drain off any superfluous moisture. From 3 to 6 canes spring from each slip. When about 3 feet high the lower leaves are wrapped round the canes, and the whole from each slip supported by bamboos. The cutting commences in January or February, the canes being then 8 or 10 feet high, and 1 to 1½ inch thick, and are passed through a mill of the rudest construction, which will be fully described when sugar-mills are treated of.

The China cane is said to be extremely hardy, standing both cold and drought, and, with abundant rain, giving out as many as thirty shoots. It resists the inroads of the white ants, which cannot penetrate its hard crust, whilst it is also proof against the teeth of the jackals. It requires, however, a stronger mill for grinding than the other varieties mentioned. Mr. Wray asserts that the Salangore cane is the finest in the Straits of Singapore, and perhaps in the world. He says that he has cut five from one stool, which were of a weight of from 17lbs. to 25 lbs. They have been known to produce 7,200 lbs. of undrained sugar per acre, equal to 5,800 lbs. of dry sugar for shipping.

Dr. Livingstone stated that sugar is cultivated in the Shire Valley, as well as in many parts of Africa near the Zambesi, and may be had for as little as one halfpenny per pound.

In all the colonies of the New World the sugar-cane flowers, but it then sends forth a shoot (*arrow*), that is, its stem elongates, and the seed-vessels prove abortive. For this reason, the bud-joints must there be used for its propagation. It is said to grow to seed, however, in India. This circumstance occurs with some other plants, which, when propagated by their roots, cease to yield fertile seeds; such as the banana, the bread-fruit, the lily, and the tulip.

In the proper season for planting, the ground is marked out by a line into rows 4 or 6 feet asunder, in which rows the canes are planted from 2 to 5 feet apart. The series of rows is divided into pieces of land 60 or 70 feet broad, leaving spaces of about 20 feet, for the convenience of passage, and for the admission of sun and air between the stems. Canes are usually planted in trenches, about 6 or 8 inches deep, made with the hand-hoe, the raised soil being heaped to one side, for covering in the young cane; into the holes a negro drops the number of cuttings intended to be inserted, the digging being performed by other negroes. The earth is then drawn about the hillocks with the hoe. This labour has been, however, in many places better and more cheaply performed by the plough; a deep furrow being made, into which the cuttings are regularly planted, and the mould then properly turned in. If the ground is to be afterwards kept clear by the horse-hoe, the rows of canes should be 5 feet asunder, and the hillocks 2½ feet distant, with only one cane left in one hillock. After some shoots appear, the sooner the horse-hoe is used the more will the plants thrive, by keeping the weeds under, and stirring up the soil. Plant-canes of the first growth have been known to yield, on the brick-mould of Jamaica, in very fine seasons, 2½ tons of sugar per acre. The proper season for planting the cane-slips containing the buds, namely, the top part of the cane stripped of its leaves, and the two or three upper joints, is in the interval between August and the beginning of November. Favoured by the autumnal weather, the young plants become luxuriant enough to shade the ground before the dry season sets in; thereby keeping the roots cool and moderately moist. By this arrangement the creole canes are ripe for the mill in the beginning of the second year, so as to enable the manager to finish his crop early in June. It is a great error for the colonist to plant canes at an improper season of the year, whereby his whole system of operations becomes disturbed, and, in a certain degree, abortive.

The withering and fall of a leaf afford a good criterion of the maturity of the cane-joint to which it belonged; so that the last eight leafless joints of two canes, which are cut the same day, have exactly the same ripeness, though one of the canes be 15 and the other only 10 months old. Those, however, cut towards the end of the dry season, before the rain begins to fall, produce better sugar than those cut in the rainy season, as they are then somewhat diluted with watery juice, and require more evaporation to form sugar. It may be reckoned a fair average product, when one pound of sugar is obtained from one gallon (English) of juice.

Rattoons (a word corrupted from *rejettons*) are the sprouts or suckers that spring from the roots or stoles of the canes that have been previously cut for sugar. They are commonly ripe in 12 months; but canes of the first growth are called plant-canes, being the direct produce of the original cuttings or germs placed in the ground, and require a longer period to bring them to maturity. The first yearly return from the roots that are cut over, are called first rattoons; the second year's growth, second rattoons; and so on, according to their age. Instead of stocking up his rattoons, holing, and planting the land anew, the planter suffers the stoles to continue in the ground, and contents himself, as the cane-fields become thin and impoverished, with supplying the vacant places with fresh plants. By these means, and with the aid of manure, the produce of sugar per acre, if not apparently equal to that from plant-canes, gives perhaps in the long run as great returns to the owner, considering the relative proportion of the labour and expense attending the different systems.

When the planted canes are ripe, they are cut close above the ground by an oblique section, and the leaves and shoots being stripped off, they are transported in bundles, in the mill-house. If the roots be then cut off a few inches below the surface of the soil, and covered up with fine mould, they will push forth more prolific offsets or rattoons than when left projecting in the common way.

The amount of sugar yielded per acre is very variously stated. In fact, the yield must vary with the different variety of canes cultivated, with the nature of the soil, the character of the season, and more than all with the more or less perfect apparatus used in manufacturing the sugar. The yield, from these causes, will vary from ½ a ton to 2½ tons of solid sugar per acre.

For the chemical examination of sugar, see Watts's 'Dictionary of Chemistry.'

Sugar Mills.—The first machines employed to squeeze the canes were mills similar to those which serve to crush apples in some cider districts, or somewhat like tan-mills. In the centre of a circular area, of about 7 or 8 feet in diameter, a vertical heavy wheel was made to revolve on its edge, by attaching a horse to a cross beam projecting horizontally from it and making it move in a circular path. The cane-pieces were strewed on the somewhat concave bed in the path of the wheel, and the juice expressed flowed away through a channel or gutter in the lowest part. This machine was tedious and unproductive. It was replaced by the vertical cylinder mill of Gonzales de Velosa; which has continued till modern times, with little variation of external form, but is now generally superseded by the sugar-mill, with horizontal cylinders.

1922

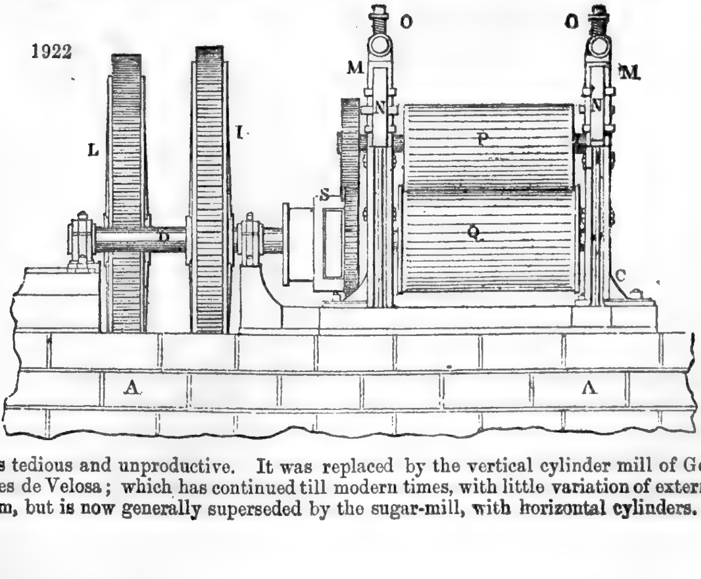
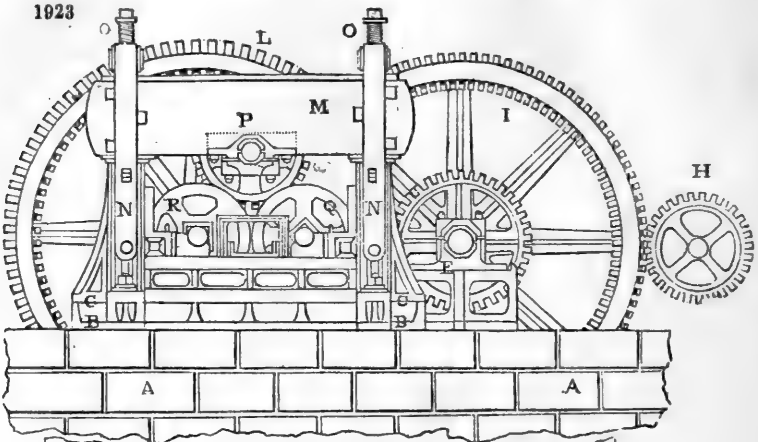


Fig. 1922, front elevation of the entire mill; *fig.* 1923, end elevation, and *Fig.* 1924, horizontal plan. *Fig.* 1925, diagram, showing the dispositions of the feeding and delivering rollers, feeding board, returner, and delivering board.

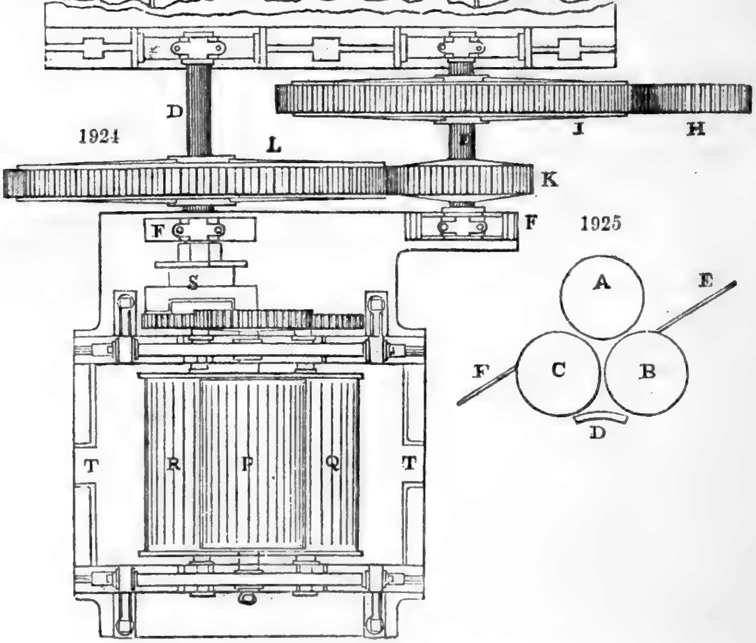
Fig. 1923, A, A, solid foundation of masonry; B, B, bed-plate; C, C, headstocks or standards; D, main shaft (seen in *fig.* 1924); E, intermediate shaft; F, F, plummer-blocks of main shaft D (seen in *fig.* 1924); H, driving pinion on the fly-wheel-shaft of engine; I, first motion mortise-wheel, driven by the pinion; K, second motion pinion, on the same shaft; L, second motion mortise-wheel, on the main shaft; M, brays of wood, holding the plummer-blocks for shaft D; N, wrought-iron straps connecting the brays to the standards C, C; O, O, regulating screws for the brays; P, top roller and gudgeons; Q, and R, the lower or feeding and delivering rollers; S, clutch for the connexion of the side of lower rollers Q, and R, to the main shaft (seen in *fig.* 1924); T, T, the drain-gutters of the mill-bed (seen only in *fig.* 1924).

1923



1924

1925



The relative disposition of the rollers is shown in the diagram, *fig.* 1925: in which A is the top roller; B, the feeding roller; C, the delivering roller; D, the returner; E, the feeding board; F, the delivering board.

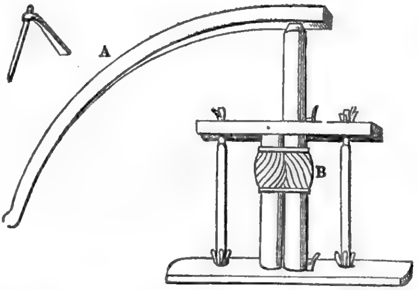
The rollers are made $2\frac{1}{4}$ inches to $2\frac{1}{2}$ inches thick, and ribbed in the centre. The feeding and delivering rollers have small flanges at their ends, (as shown in *fig.* 1924), between which the top roller is placed; these flanges prevent the pressed canes or *megass* from working into the mill-bed. The feeding and top rollers are generally fluted, and sometimes diagonally, enabling them the better to seize the canes from the feeding-board. It is, however, on the whole, considered better to flute the feeding roller only, leaving the top and delivery rollers plane; when the top roller is fluted, it should be very slightly, for, after the work of a few weeks, its surface becomes sufficiently rough to bite the canes effectively. The practical disadvantage of fluting the delivering rollers, is in the grooves carrying round a portion of liquor, which is speedily absorbed by the spongy megass, as well as in breaking the megass itself, and thus causing great waste.

In working this mill, the feeding roller is kept about half an inch distant from the upper roller, but the delivering roller is placed about $\frac{1}{8}$th of an inch from it.

The canes are thrown upon the feeding board, and spread so that they may cross each other as little as possible. They are taken in by the feeding rollers, which split and slightly press them: the liquor flows down, and the returner guiding the canes between the top and delivering rollers, they receive the final pressure, and are turned out on the mill-floor, while the liquor runs back and falls into the mill-bed. The megass, then in the state of *pith*, adhering to the skin of the cane, is tied up in bundles, and after being exposed a short time to the sun, is finally stored in the megass-house for fuel. By an improvement in this stage of the process, the megass is carried to the megass-house by a carrier chain, worked by the engine.

The sugar-mill at Chica Ballapura is worked by a single pair of buffaloes or oxen, going round with the lever A, *fig.* 1926, which is fixed on the top of the right-hand roller. The two rollers have endless screw-heads B, which are formed of four spiral grooves and four spiral ridges, cut in opposite directions, which turn into one another when the mill is working. These rollers and their heads are of one piece, made of the toughest and hardest wood that can be got, and such as will not impart a bad taste to the juice. They are supported in a thick strong wooden frame, and their distance from each other is regulated by means of wedges, which pass through mortises in the frame-planks, and a groove made in a bit of some sort of hard wood, and press upon the axis of one of the rollers. The axis of the other presses against the left-hand side of the hole in the frame-boards. The cane-juice runs down the rollers, and through a hole in the lower frame-board, into a wooden conductor, which carries it into an earthen pot. Two long-pointed stakes or piles are driven into the earth, to keep the mill steady, which is all the fixing it requires. The under part of the lowermost plank of the frame rests upon the surface of the ground, which is chosen level and very firm, that the piles may hold the faster. A hole is dug in the earth, immediately below the spout of the conductor, to receive the pot.

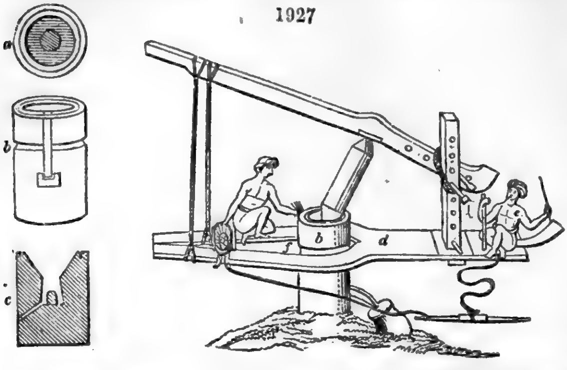
1926



The mill used in Burdwan and near Calcutta is simply two small wooden cylinders, grooved, placed horizontally, close to each other, and turned by two men, one at each end. This simple engine is said to express the juice completely, but slowly. It is very cheap, the prime cost not being two rupees; and being easily moved from field to field, it saves much labour in the carriage of the cane. Notwithstanding this advantage, so rude a machine must leave a large proportion of the richest juice in the cane-trash.

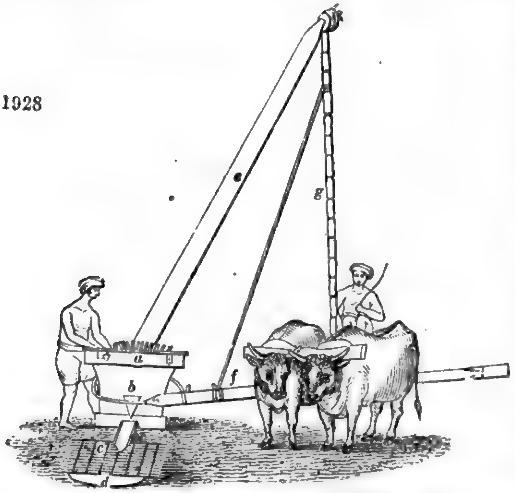
The sugar-mill of Chinapatam, *fig.* 1927, consists of a mortar, lever, pestle, and regulator. The mortar is a tree about 10 feet in length and 14 inches in diameter: *a* is a plan of its upper end; *b* is an outside view; and *c* is a vertical section. It is sunk perpendicularly into the earth, leaving one end 2 feet above the surface. The hollow is conical, truncated downwards, and then becomes cylindrical, with a hemispherical projection in its bottom, to allow the juice to run freely to the small opening that conveys it to a spout, from which it falls into an earthen pot. Round the upper mouth of the cone is a circular cavity, which collects any of the juice that may run over from the upper ends of the pieces of cane; and thence a canal conveys this juice down the outside of the mortar, to the spout. The beam *d*, is about 16 feet in length and 6 inches in thickness, being cut out from a large tree that is divided by a fork into two arms. In the fork an excavation is made for the mortar *b*, round which the beam turns horizontally. The surface of this excavation is secured by a semicircle of strong wood. The end towards the fork is quite open, for changing the beam without trouble. On the undivided end of the beam sits the bullock-driver, *e*, whose cattle are yoked by a rope which comes from the end of the beam; and they are prevented from dragging out of the circle by another rope, which passes from the yoke to the forked end of the beam. On the arms, *f*, a basket is placed, to hold the cuttings of cane; and between this and the mortar sits the man who feeds the mill. Just as the pestle comes round, he places the pieces of cane sloping down into the cavity of the mortar; and after the pestle has passed, he removes those away that have been squeezed.

1927



The following describes the primitive rude mill and boiler used in preparing the extract of sugar-cane, and which are usually let to the ryots by the day. The mill in Dinajpur, *fig.* 1928, is on the principle of a pestle and mortar. The pestle, however, does not beat the canes, but is rubbed against them, as is done in many chemical triturations; and the moving force is two oxen. The mortar is generally a tamarind tree, one end of which is sunk deep in the ground, to give it firmness. The part projecting, *a*, may be about 2 feet high and a foot and a half in diameter; and in the upper end a hollow is cut, like the small segment of a sphere. In the centre of this, a channel descends a little way perpendicularly, and then obliquely to one side of the mortar, so that the juice as squeezed from the cane, runs off by means of a spout, *b*, into a strainer *c*, through which it falls into an earthen pot that stands in a hole, *d*, under the spout. The pestle, *e*, is a tree about 18 feet in length, and 1 foot in diameter, rounded at its bottom, which rubs against the mortar, and which is secured in its place by a button or knob that goes into the channel of the mortar. The moving force is applied to a horizontal beam, *f*, about 16 feet in length, which turns round about the mortar, and is fastened to it by a bent bamboo. It is suspended from the upper end of the pestle by a bamboo, *g*, which has been cut with part of the root, in which is formed a pivot that hangs on the upper point of the pestle. The cattle are yoked to the horizontal beam, at about 10 feet from the mortar, move round it in a circle, and are driven by a man who sits on the beam to increase the weight of the triturating power. Scarcely any machine more

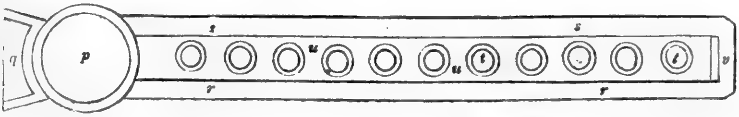
1928



miserable can be conceived; and it would be totally ineffectual, were not the cane cut into thin slices. This is a troublesome part of the operation. The grinder sits on the ground, having before him a bamboo-stake, which is driven into the earth with a deep notch formed in its upper end. He passes the canes gradually through this notch, and at the same time cuts off the slices with a kind of rude chopper.

The *boiling apparatus* is somewhat better contrived, and is placed under a shed, though the mill is without shelter. The fireplace is a considerable cavity dug in the ground, and covered with an iron boiler, *p*, *fig.* 1929. At one side of this is an opening, *q*, for throwing in fuel; and opposite to this is another opening, which communicates with the horizontal flue. This is formed by two parallel mud walls, *r*, *r*, *s*, *s*, about 20 feet long, 2 feet high, and 18 inches distant from each other. A row of eleven earthen boilers, *t*, is placed on these walls, and the interstices, *u*, are filled with clay, which completes the furnace-flue, an opening, *v*, being left at the end, for giving vent to the smoke.

1929



The juice, as it comes from the mill, is first put into an earthen boiler that is most distant from the fire, and is gradually removed from one boiler to another, until it reaches the iron one, where the process is completed. The inspissated juice that can be prepared in twenty-four hours by such a mill, with sixteen men and twenty oxen, amounts to no more than 476 lbs.; and it is only in the southern parts of the district, where the people work night and day, that the sugar-works are productive. In the northern districts, the people work only during the day, and inspissate about one-half the quantity of juice.

Of the Manufacture of Sugar in the West Indies.—Cane-juice varies exceedingly in richness, with the nature of the soil, the culture, the season, and variety of the plant. When left to itself in the colonial climates, the juice runs rapidly into the acetous fermentation. Hence arises the necessity of subjecting it immediately to clarifying processes, speedy in their action. When deprived of its green fecula and glutinous extractive, it is still subject to fermentation; but this is now of the vinous kind. The juice flows from the mill through a wooden gutter lined with lead, and being conducted into the sugar-house, is received in a set of large pans or cauldrons, called 'clarifiers.' On estates which make on an average, during crop time, from 15 to 20 hogsheads of sugar a week, three clarifiers, of 400 gallons' capacity each, are sufficient. With pans of this dimension, the liquor may be drawn off at once by a stopcock or syphon, without disturbing the feculencies after they subside. The clarifiers are sometimes placed at one end, and sometimes in the middle of the house, particularly if it possesses a double set of evaporating pans.

Whenever the stream from the mill-cistern has filled the clarifier with fresh juice, the fire is lighted, and the *temper*, or dose of slaked lime, diffused uniformly through a little juice, is added. If an albuminous emulsion be used to promote the clarifying, very little lime will be required; for recent cane-liquor contains no appreciable portion of acid to be saturated. In fact, the lime and alkalis in general, when used in small quantity, seem to coagulate the glutinous extractive matter of the juice, and thus tends to brighten it up. Excess of lime may also be corrected by a little alum-water. Where canes grow on a calcareous marly soil, in a favourable season the saccharine matter gets so thoroughly elaborated, and the glutinous mucilage so completely condensed, that a clear juice and a fine sugar may be obtained without the use of lime.

As the liquor grows hot in the clarifier, a scum is thrown up, consisting of the coagulated feculencies of the cane-juice. The fire is now gradually urged till the temperature approaches the boiling point; to which, however, it must not be suffered to rise. It is known to be sufficiently heated, when the scum rises in blisters, which break into white froth; an appearance observable in about forty minutes after kindling the fire. The damper being shut down, the fire dies out; and after an hour's repose, the clarified liquor is ready to be drawn off into the last and largest in the series of evaporating pans. In the British colonies, these are merely numbered 1, 2, 3, 4, 5, beginning at the smallest, which hangs right over the fire, and is called the *teache*; because in it the trial of the syrup, by *touch*, is made. The flame and smoke proceed in a straight line along a flue to the chimney-stalk at the other end of the furnace. The area of this flue proceeds, with a slight ascent from the fire, to the aperture at the bottom of the chimney; so that between the surface of the grate and the bottom of the teache there is a distance of 28 inches; while between the bottom of the flue and that of the *grand*, No. 5, at the other end of the range, there are barely 18 inches.

In some sugar-houses there is planted, in the angular space between each boiler, a basin, one foot wide and a few inches deep, for the purpose of receiving the scum which thence flows off into the *grand copper*, along a gutter scooped out on the margin of the brickwork. The skimmings of the *grand* are thrown into a separate pan, placed at its side. A large cylindrical *cooler*, about 6 feet wide and 2 feet deep, has been placed in certain sugar-works near the teache, for receiving successive charges of its inspissated syrup. Each finished charge is called a *skipping*, because it is skipped or laded out. The term *striking* is also applied to the act of emptying the teache. When upon one skipping of syrup in a state of incipient granulation in the cooler, a second skipping is poured, this second congeries of saccharine particles agglomerates round the first as *nuclei* of crystallisation, and produces a larger grain; a result improved by each successive skipping. This principle has been long known to the chemist, but does not seem to have been always properly considered or appreciated by the sugar-planter.

From the above-described cooler, the syrup is transferred into wooden chests or boxes, open at top, and of a rectangular shape, also called *coolers*, but which are more properly crystallisers or granulators. These are commonly six in number; each being about 1 foot deep, 7 feet long, and 5 or 6 feet wide. When filled, such a mass is collected as to favour slow cooling, and consequently large-grained crystallisation. If these boxes be too shallow, the grain is exceedingly injured, as may be easily shown by pouring some of the same syrup on a small tray; when, on cooling, the sugar will appear like a muddy soft sand.

The due concentration of the syrup in the teache is known by the boiler, by the appearance of a drop of the syrup pressed and then drawn into a thread between the thumb and fore-finger. The thread eventually breaks at a certain limit of extension, shrinking from the thumb to the suspended finger, in lengths somewhat proportional to the inspissation of the syrup. But the appearance of granulation in the thread must also be considered; for a viscid and damaged syrup may give a long enough thread, and yet yield almost no crystalline grains when cooled. Tenacity and granular aspect must therefore be both taken into the account, and will continue to constitute the practical guides to the negro boiler, till a less barbarous mode of concentrating cane-juice be substituted for the present *naked teache*, or *sugar frying-pan*.

A viscous syrup containing much gluten and sugar, altered by lime, requires a higher temperature to enable it to granulate than a pure saccharine syrup; and therefore the thermometer, though a useful aid, can by no means be regarded as a sure guide, in determining the proper instant for *striking* the teache.

The colonial *curing-house* is a spacious building, of which the earthen floor is excavated to form the molasses-reservoir. This is lined with sheet-lead, boards, tarras, or other retentive cement; its bottom slopes a little, and it is partially covered by an open massive frame of joist-work, on which the plotting casks are set upright. These are merely empty sugar-hogsheads, without headings, having 8 or 10 holes bored in their bottoms, through each of which the stalk of a plantain-leaf is stuck, so as to protrude downwards 6 or 8 inches below the level of the joists, and to rise above the top of the cask. The act of transferring the crude concrete sugar from the crystallisers into these hogsheads, is called *potting*. The bottom holes, and the spongy stalks stuck in them, allow the molasses to drain slowly downwards into the sunk cistern. In the common mode of procedure, sugar of average quality is kept from 3 to 4 weeks in the curing-house; that which is soft-grained and glutinous must remain 5 or 6 weeks. The curing-house should be close and warm, to favour the liquefaction and drainage of the viscid molasses.

Out of 120,000,000 lbs. of raw sugar which used to be annually shipped by the St. Domingo planters, only 96,000,000 lbs. were landed in France, according to the authority of Dutrone, constituting a loss by drainage in the ships of 50 per cent. The average transport waste in the sugars of the British colonies cannot be estimated at less than ·12 per cent., or altogether upwards of 27,000 tons! What a tremendous sacrifice of property!

Syrup intended for forming clayed sugar must be somewhat more concentrated in the teache, and run off into a copper cooler, capable of receiving three or four successive skippings. Here it is stirred to ensure uniformity of product, and is then transferred by ladles into conical moulds, made of coarse pottery or of sheet iron, having a small orifice at the apex, which is stopped with a plug of wood wrapped in a leaf of maize. These conical pots stand with the base upwards. As their capacity, when largest, is considerably less than that of the smallest potting-casks, and as the process lasts several weeks, the claying-house requires to have very considerable dimensions. Whenever the syrup is properly granulated, which happens usually in about 18 or 20 hours, the plugs are removed from the apices of the cones, and each is set on an earthen pot to receive the drainings. At the end of 24 hours the cones are transferred over empty pots, and the molasses contained in the former ones is either sent to the fermenting-house or sold. The claying now begins, which consists in applying to the smoothed surface of the sugar at the base of the cone a plaster of argillaceous earth, or tolerably tenacious loam in a pasty state. The water diffused among the clay escapes from it by slow infiltration, and descending with like slowness through the body of the sugar, carries along with it the residuary viscid syrup, which is more readily soluble than the granulated particles. Whenever the first magma of clay has become dry, it is replaced by a second; and this occasionally in its turn by a third, whereby the sugar-cone gets tolerably white and clean. It is then dried in a stove, cut transversely into *frusta*, crushed into a coarse powder on wooden trays, and shipped off for Europe. Clayed sugars are sorted into different shades of colour according to the part of the cone from which they were cut. The clayed sugar of Cuba, which is sun-dried, is called 'Havannah sugar,' from the name of the shipping port.

Clayed sugar can be made only from the ripest cane-juice, for that which contains much gluten would be apt to get too much burned by the ordinary process of boiling to bear the claying operation. The syrups that run off from the second, third, and fourth applications of the clay-paste, are concentrated afresh in a small building apart, called the *refinery*, and yield tolerable sugars. Their drainings go to the molasses-cistern. The cones remain for 20 days in the claying-house before the sugar is taken out of them.

Claying is seldom had recourse to in the British plantations, on account of the increase of labour, and diminution of weight in the produce, for which the improvement in quality yields no adequate compensation. Such, however, was the esteem in which the French consumers held clayed-sugar, that it was prepared in 400 plantations of St. Domingo alone.

SUGAR REFINING.—The raw or Muscovado sugar, as usually imported, is not in a state of sufficient purity for use. The sugar is blended with more or less of fruit- and grape-sugars, with sand and clay, with albuminous- and colouring-matter, chiefly caramel. To separate the pure sugar, the plan formerly adopted was to add blood, eggs, and lime-water to a solution of the raw sugar, and after applying heat, to remove the thick scum of coagulated albumen, which also removed a considerable portion of colouring-matter. The clear liquid was concentrated, and the semi-crystalline mass being placed in conical moulds, as much of the molasses as would drain by gravitation was allowed to escape from the points of the moulds, and the remainder was expelled by allowing water or a solution of pure sugar to trickle through the mass of crystals. The loaves, being trimmed into shape and dried, were fit for sale.

By this process only a small proportion of the sugar was made into loaf. The method of removing the colouring-matter was crude, imperfect, and expensive; and the high temperature requisite for the fermentation of the syrup not only injured its colour, but converted a large proportion of the sugar into the uncrystallisable variety.

These defects were remedied, to a great extent, by the adoption of Howard's vacuum-pan, for the concentration of syrups under diminished atmospheric pressure, and consequently at a low temperature together with the use of filtering-beds of animal-charcoal for the removal of colouring-matter.

There are three classes of sugar-refineries in this country, the chief productions of which are, respectively:—

1st. Loaf-sugar.

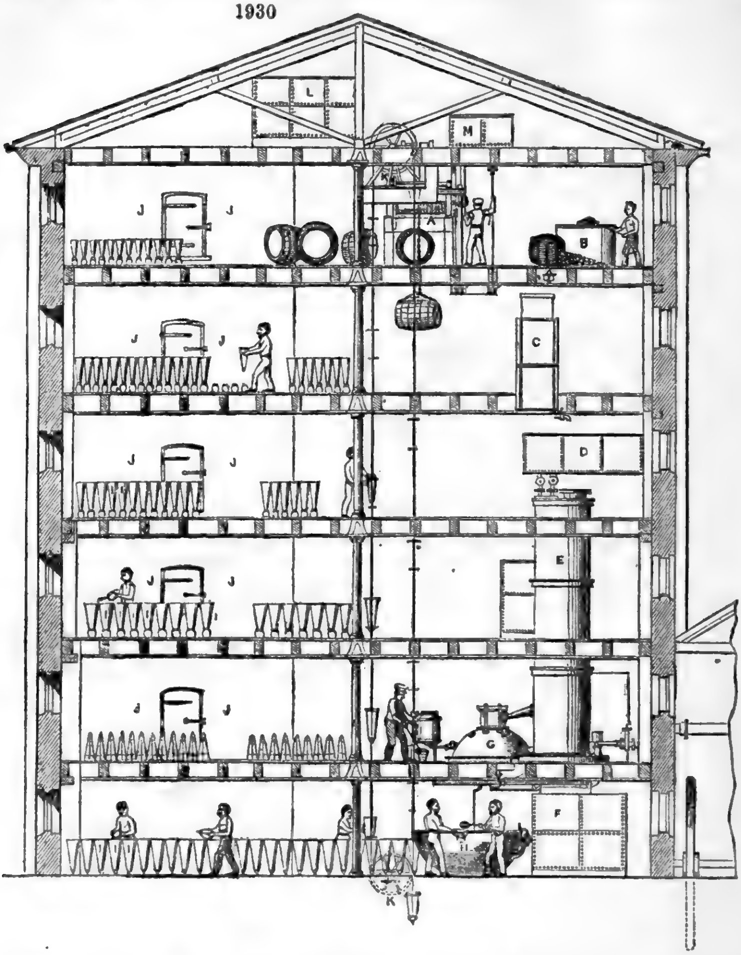
2nd. Crystals (*i.e.* large, well-formed, dry white crystals of sugar).

3rd. Crushed sugar.

In the former two, good West India, Havannah, Mauritius, or Java sugar are almost exclusively used. In the last, all classes of sugar are indiscriminately employed. The manufacture of loaf-sugar is chiefly carried on in London; of crystals, in Bristol and Manchester; of crushed sugar, in Liverpool, Greenock, and Glasgow. Besides these places, which are the chief seats of the sugar-refining trades, this branch of industry is carried on more or less at Plymouth, Southampton, Goole, Sheffield, Newton (Lancashire), and Leith. The methods vary a little in different refineries; but the following description refers to the most modern and best conducted which are to be found in this country. The general arrangements of a sugar-house are shown in *fig.* 1930.

LOAF-SUGAR.—*Solution.* The raw sugar is emptied from the hogsheads, boxes, or mats, as the case may be, and discharged through a grating in the floor into a copper pan, about 8 feet in diameter. This dissolving pan is sometimes, although incorrectly, called 'a defecator,' it was formerly called 'a blow-up,' from the practice of blowing steam into it, but the practice and the name are now antiquated. Hot water is added, and the solution is facilitated by the action of an agitator, or stirrer, kept in motion by the steam-engine. The proportions of sugar and water are regulated so that the liquid attains a specific gravity of about 1·250, or 29° Beaumé, as a higher density than this would interfere with subsequent processes. A copper coil or casing to the pan, heated by steam, furnishes the means of raising the liquid to a temperature of 165°. The plan of boiling the 'liquor' is becoming gradually disused. If the solution is acid, sufficient lime-water is added to make it neutral. The use of blood, which was formerly added at this stage, is in most cases dispensed with; the advantage arising from its use is readily obtained from the employment of an increased amount of animal-charcoal in a subsequent process, while the mischief arising from the introduction of nitrogenous matter so prone to decompose is avoided. Some machinery is used for crushing the hard lumps to facilitate solution.

1930

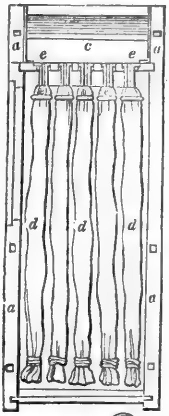


Removal of insoluble matter.—The liquor having been brought to the requisite density and temperature, and also being perfectly neutral, is passed through the bag-filter.

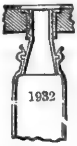
The apparatus consists of an upright square iron or copper case, *a*, *a*, *fig.* 1931, about

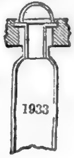
6 or 8 feet high, furnished with doors; beneath is a cistern with a pipe for receiving and carrying off the filtered liquor; and above the case is another cistern, *c*. Into the upper cistern the syrup is introduced, and passes thence into the mouths *e*, *e*, of the several filters, *d*, *d*. These consist each of a bag of thick twilled cotton of cloth, about 2 feet in diameter and 6 or 8 feet long, which is inserted into a narrow 'sheath,' or bottomless bag of canvas, about 5 inches in diameter, for the purpose of folding the filter-bag up into a small space, and thus enabling a great extent of filtering surfaces to become pressed into one box. The orifice of each compound bag is tied round a conical brass mouth-piece or nozzle *e*, which screws tight into a corresponding opening in the bottom of the upper cistern. From 40 to 400 bags are mounted in each filter-case. The liquor which first passes is generally turbid, and must be pumped back into the upper cistern, for refiltration. The interior of the case is furnished with a pipe for injecting steam, which is occasionally used for warming the case. *Fig.* 1932 shows one mode of forming the funnel-shaped nozzles of the bags, in which they are fixed by a bayonet-catch. *Fig.* 1933 shows the same made fast by means of a screwed cap, which is more secure.

1931



When the bags are fouled from the accumulation of clay and a slimy substance on their inner surfaces, the filter is unpacked, the bags withdrawn from the sheaths, and well washed in hot water. This washing is usually performed with a dash-wheel, or some one of the numerous kinds of washing-machines now in use. Perhaps that of Manlove and Alliott, of Nottingham, is in greatest favour. The dirty water, with the addition of a little lime, is smartly boiled, and after some hours being allowed for subsidence, the supernatant, clear, weak solution of sugar is removed and used in the first process (solution), while the muddy residue is placed in canvas bags and subjected to pressure. The residue, technically called *scum*, is thrown away.


1932


1933

Removal of colour.—The liquor issuing from the bag-filters generally resembles in colour dark sherry wine. To render this colourless it is passed through deep filtering-beds of granulated burnt bones or animal-charcoal. When this substance was first introduced, beds of a few inches in depth were considered sufficient, but the quantity of charcoal used per ton of sugar has steadily increased, and filters of no less a depth than 50 feet are now sometimes used.

Cylinders of wrought or cast iron, varying in diameter from 5 to 10 feet, and in height from 10 to 50, having a perforated false bottom a couple of inches above the true one, are filled with granulated animal-charcoal.

The grain varies from the size of turnip-seed to that of peas, some refiners preferring it fine, and others coarse.

Liquor from the bag-filters is run on to the charcoal till the cylinder is perfectly filled, when the exit tap at the bottom is opened, and a stream of dense saccharine fluid, perfectly colourless, issues forth. The amount of sugar which the charcoal will discolour depends upon the age and composition of the charcoal, the degree of perfection with which the previous revivification has been performed, and the quality, colour, and density of the liquor to be operated upon. One ton of charcoal is sometimes used to purify two tons of sugar; and in at least one refinery, where inferior sugar is operated on, two tons of charcoal serve for one ton of sugar. In most provincial refineries about one ton of charcoal is used to one of sugar; but in London, from the dearness of fuel and other causes, a smaller proportion of charcoal is employed. The liquor from the charcoal filter, at first colourless, becomes slightly tinged, and in course of time, varying from 24 hours to 72, the power of the charcoal becomes exhausted, the partially decoloured syrup is passed through a fresh charcoal filter, and the sugar is washed out from the charcoal by means of hot water. The charcoal is ready to be removed for revivification, which process has already been described.

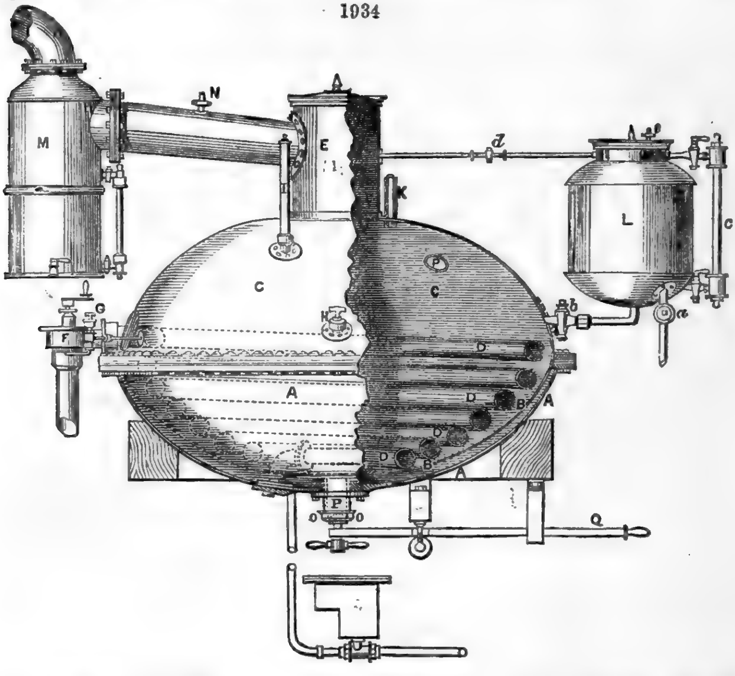
Concentration.—The next process in sugar-refining is the evaporation of the clarified syrup to the granulating or crystallising point. The more rapidly this is effected, and the less the heat to which it is subjected, the better and greater is the product in sugar-loaves. No apparatus answers the refiner's double purpose of safety and expedition so well as the vacuum-pan.

The vacuum-pan, invented by Howard, and patented in the year 1812, is an enclosed copper vessel, heated by steam, passing through one or more copper coils, and a steam-jacket. The vapour arising from the boiling solution of sugar is condensed by an injection of cold water, the arrangement of which, and the maintenance of a vacuum, closely resemble the condenser, injection, and air-pump of an ordinary condensing steam-engine.

Fig. 1934 shows the structure of a single vacuum-pan. The horizontal diameter of the copper spheroid C C, is from 7 to 10 feet; the depth of the under hemisphere A, is at least 2 feet from the level of the flange; and the height of the dome-cover is from 3 to 5 feet. The two hemispheres (of which the inferior one is double, or has a steam-jacket), are put together by bolts and screws, to preserve the joints tight against atmospheric pressure.

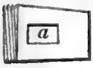
The steam enters through the valve F, traversing the copper coil D, and filling the steam-jacket, the condensed water issuing from a small pipe below. C represents the dome of the vacuum-pan, the vapour from which, passing in the direction of N, allows any particles of sugar carried over by the violence of the ebullition to be deposited in the receiver, M.

1934

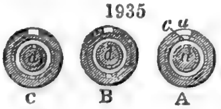


The vapour is condensed by jets of cold water issuing from a perforated pipe, and the water, uncondensed vapour, and air, are removed by the action of a powerful air-pump. L is the measure cistern, from which the successive charges are admitted into the pan; I and K represent respectively a thermometer and a barometer: the former being required to indicate the temperature of the boiling syrup, and the latter the diminished atmospheric pressure within the pan. P is the discharge cock; and H. the proof-stick, is an apparatus inserted air-tight into the cover of the vacuum-pan, and which dips down into the syrup, serving to take out a sample of it, without allowing air to enter. It is shown in detail, in *fig.* 1939, which represents a cylindrical rod, capable of being screwed air-tight into the pan in an oblique direction downwards. The upper or exterior end is open; the under, which dips into the syrup is closed, and has on one side a slit *a* (*figs.* 1936, 1939), or notch, about ½ in. wide. In this external tube, there is another shorter tube *b*, capable of moving round it, through an arc of 180°. An opening upon the under end *e*, corresponds with the slit in the outer tube, so that both may be made to coincide, *fig.* 1934, A. A plug *d*, is put in the interior tube, but so as not to shut it entirely. Upon the upper end there is a projection or pin, which catches in a slit of the inner tube, by which this may be turned round at pleasure. In the lower end of the plug there is a hole *e*, which can be placed in communication with the lateral openings in both tubes. Hence it is possible, when the plug and the inner tube are brought into the proper position, A, *fig.* 1935, to fill the cavity of the rod with the syrup, and to take it out without allowing any air to enter. In order to facilitate the turning of the inner tube within the outer, there is a groove in the under part, into which a little grease may be introduced.

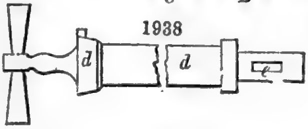
1936



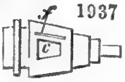
1935



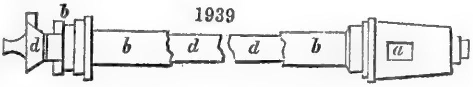
1938



1937



1939



Whenever a proof has been taken, the plug must be placed in reference to the inner tube, as shown in *fig.* 1935, C, and then turned into the position A; when the cavity of the plug will again be filled with syrup. C must now be turned back to the former position, whereby all intercourse with the vacuum-pan is cut off; the plug being drawn out a little, and placed out of communication with the inner tube. The plug is then turned into the position B, drawn out, and the proof examined by the fingers.

The method of using the vacuum-pan varies with the character of the grain required to be produced. On commencing boiling, the syrup should be run in as quickly as possible, till the whole heating-surface is covered, when the steam is turned on, and the evaporation conducted at a temperature of from 170° to 180° Fahr. As soon as the syrup begins to granulate, the temperature becomes reduced to 160°; and finally just before the evaporation is completed, and the sugar ready to be discharged into the heater, it is further reduced, and approaches 145°, being the lowest temperature at which proof-sugar boils, 3 inches from a perfect vacuum. When the sugar-boiler ascertains, by withdrawing a sample of the syrup by means of the proof-stick, and examining it against the light between his finger and thumb, that the crystals are in a sufficiently forward state for his purpose, he adds another measureful to that already in the pan, and the same process is repeated till the whole charge has been admitted. After each successive charge the crystals continue increasing in size to the end of the operation, those first formed acting as nuclei: a *skip*, as it is technically called, or a panful of the concentrated sugar, may be made in from two to four hours from the commencement of the boiling. If a fine-grain sugar be required, greater quantities of syrup are admitted at each charge of the measure, and *vice versâ.*

Making of Loaf-sugar.—The proof-sugar at a temperature not exceeding 145° is then let down through a cock or valve in the bottom of the pan into the heater. The sugar-liquor consists at this stage of the process of a large number of small crystals floating in a medium of syrup.

The heater is an open copper pan of about the same capacity as the vacuum-pan, and is furnished with a steam-jacket and provided with an agitator,—in fact, it closely resembles the dissolving-pan used for the first process. The object to be attained in the heater is to raise the sugar to a temperature of 180°, which has been found by practice to be the point best adapted for hardening and completing the formation of the crystals, during which process the sugar is constantly stirred.

The sugar is then run out through a cock in the bottom of the heater into a ladle, from whence it is poured into moulds or cones of sheet iron strongly painted. The sizes of the moulds vary, from a capacity of 10-lb. *loaves* to that of 56-lb. *bastards*—a kind of soft brown sugar obtained by the concentration of the inferior syrups. These moulds have the orifices at their tips closed with nails inserted through pieces of cloth or India-rubber, and are set up in rows close to each other, in an apartment adjoining the heaters. Here they are left several hours, commonly the whole night, after being filled, till their contents become solid, and they are lifted next morning into an upper floor, kept at a temperature of about 100° by means of steam-pipes, and placed over gutters to receive the syrup drainings; the plugs being first removed, and a steel wire, called 'a piercer,' being thrust up to clear away any concretion from the tip. The syrup which flows off spontaneously is called 'green syrup.' It is kept separate. In the course of one or two days, when the drainage is nearly complete, some finely-clarified syrup, made from a filtered solution of fine raw sugar is poured to the depth of about an inch upon the base of each cone, the surface having been previously rendered level and solid by an iron tool, called a 'bottoming trowel.' The liquor, in percolating downwards, being already a saturated syrup, can dissolve none of the crystalline sugar, but only the coloured matter and molasses; whereby, at each successive liquoring, the loaf becomes whiter, from the base to the apex.

To economise the quantity of 'fine liquor' used, it is usual to give a first and even a second liquor of an inferior quality before applying the finishing liquor, which is a dense and almost saturated solution of fine sugar absolutely free from colour. A few moulds, taken promiscuously, are emptied from time to time, to inspect the progress of the blanching operation; and when the loaves appear to have acquired as much *colour*, according to the language of refiners, as is wanted for the particular market, they are removed from the moulds, turned on a lathe at the tips, if necessary, set for a short time upon their bases, to diffuse their moisture equally through them, and then transferred into a stove heated to 130° or 140° by steam-pipes, where they are allowed to remain for two or three days, till they are baked thoroughly dry. They are then taken out of the stove, and put up in paper for sale.

The drainage of the last portion of the liquor from the moulds is sometimes accelerated by means of a vacuum. Centrifugal action has been also proposed for this purpose, but has not been found to succeed.

The drainings from the moulds which are collected in gutters, and run into cisterns are boiled, and form an inferior quality of sugar. The drainings from this last sugar consist of treacle or syrup, which is always obtained as a final product.

Manufacture of Crystals.—The use of centrifugal action for the separation of liquids and solids has been adopted in the arts for many years; its application for the separation of syrup and sugar occurred to several individuals, but it was best effected by means of the admirable hydro-extractor, invented by Manlove and Alliott of Nottingham. Various modifications of this machine have been proposed and patented, but it is very doubtful whether anything that has been yet devised has improved upon the original machine.

The semi-fluid mass is removed to the centrifugal machines with the least possible delay, and each machine barely attains its maximum speed before the syrup is discharged. To cleanse the surface of the crystals they are washed with liquor, sprinkled in the machine by means of a watering-can, a few pints being used to each cwt.

By this process the percentage of sugar obtained from the first and each separate crystallisation is considerably less than that obtained in the making of loaf-sugar or the ordinary method of making 'crushed,' though the *total* product does not vary materially, being rather more than that of the former where the product is stove-dried and less than the latter, which is sold damp. The drainage is diluted, filtered through animal-charcoal, boiled, and passed through the centrifugal machines, and results in a second quality of sugar, the crystals being smaller. The drainage from this is treated in a similar manner, and a third quality of crystals is the result. A fourth quality of crystals is also sometimes obtained, the drainage from which is again boiled and laid aside in large moulds to crystallise for about a week, when treacle and a low quality of 'pieces' is the final result. The drainages are sometimes filtered along with inferior qualities of raw sugar.

The difficulty with which these large and beautiful crystals obtained by this process dissolve, is an obstacle to their extensive consumption; but Messrs. Finzel, of Bristol, have lately introduced a sugar in smaller crystals, which dissolves almost as readily as loaf-sugar.

Crushed Sugar.—This process closely resembles the manufacture of loaf-sugar, but the raw sugar used is generally of an inferior quality. The filtration through the animal-charcoal is in consequence not so perfect; the concentration resembles that of loaf-sugar, but the use of a heater is dispensed with, and the process of liquoring is also dispensed with where practicable. The first crystallisation is called 'crushed' and the second 'pieces,' the drainage from which goes by the name of 'syrup.' When this syrup is diluted, filtered through animal-charcoal, and concentrated, it is called 'golden syrup.'

Treatment of Molasses.—Foreign and colonial molasses, containing a large proportion of crystallisable sugar, are purchased by refiners. The Muscovado molasses from Cuba, from Porto Rico, Antigua, and Barbadoes, are esteemed the best, but the quality of molasses deteriorates as improvements in the manufacture of sugar are introduced on the plantations. The treatment of molasses formerly was simple; it was merely concentrated and allowed to stand for several weeks in large moulds to drain. The liquid was sold as treacle, and the impure soft, dark sugar, called 'bastards,' found a market amongst the poorer classes, especially in Ireland.

The better plan is to dilute the molasses, filter it through animal-charcoal, and concentrate to the crystallising-point, but without forming crystals. This readily crystallises in the moulds, and in place of the bastards and treacle, a bright yellow sugar and a fair quality of syrup are the result. Good molasses yields 40 per cent. sugar, 40 per cent. syrup, the remaining 20 per cent. being water, dirt, and loss.

Palm- or Date-sugar.—Many trees of the palm tribe yield a copious supply of sweet juice, which, when boiled down, gives a dark-brown deliquescent, raw sugar, called in India *Jaggery.* The wild date-palm and the gommuto-palm yield the largest proportion of this kind of sugar, which is chemically identical with the sugar from the cane, though the crudeness of the manufacture is very injurious to it, and causes a large proportion to assume the uncrystallisable condition. One twenty-fourth of all the cane-sugar extracted for useful purposes is obtained from the palm-tree.

Beet-root Sugar.—The extraction of sugar from beet-root, has become an important manufacture in several countries on the Continent, especially in France and Germany. It was developed in consequence of the difficulty of obtaining colonial sugar in France during the blockade in the time of Napoleon I. See BEET-ROOT.

The proportion of sugar varies very much. The average proportion of sugar extracted from beet is 6 per cent., though it is stated that 7½ per cent. is obtained in some well-conducted manufactories. In France and Belgium the average yield is 14 or 15 tons of beet to the acre, while about Magdeburg they do not exceed 10 to 12 tons, but the latter are richer in sugar.

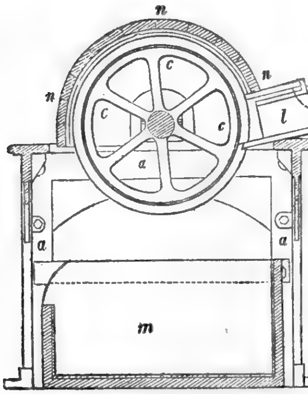
During the first year of its life the root is developed to its full size, and secretes the whole amount of sugar which, in the natural life of the plant, furnishes the material for the growth and maturity of its upper part.

The first manipulations to which the beets are exposed are intended to clear them from the adhering earth and stones as well as the fibrous roots and portions of the neck. The roots are washed by a rotatory movement upon a grating made like an Archimedes' screw, formed round the axis of a squirrel-cage cylinder, which is laid horizontally beneath the surface of water in an oblong trough. It is turned rapidly by means of a toothed wheel and pinion. The roots, after being sufficiently agitated in the water, are tossed out by the rotation at the opposite end of the cylinder.

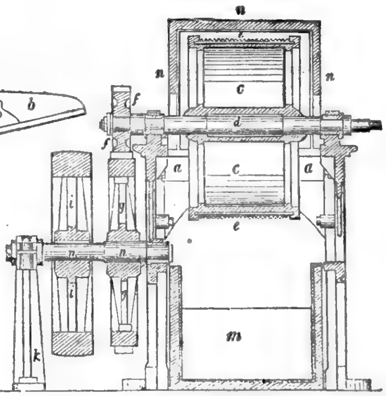
The parenchyma of the beet is a spongy mass, whose cells are filled with juice. The cellular tissue itself, which forms usually only a twentieth or twenty-fifth of the whole weight, consists of ligneous fibre. Compression alone, however powerful, is inadequate to force out all the liquor which this tissue contains. To effect this object, the roots must be subjected to the action of an instrument which will tear and open up the greatest possible number of these cells. Experiments have, indeed, proved, that by the most considerable pressure, not more than 40 or 50 per cent. in juice can be obtained from the beet; whilst the pulp procured by the action of a grater produces from 75 to 80 per cent.

The beet-root rasp is represented in *figs.* 1940, 1941. *a*, *a* is the framework of the machine; *b*, the feed-plate, made of cast iron, divided by a ridge into two parts; *c*, the hollow drum; *d*, its shaft, upon either side of whose periphery nuts are screwed for securing the saw blades *e*, *e*, which are packed tight against each other by means of laths of wood; *f* is a pinion upon the shaft of the drum, into which the wheel *g* works, and which is keyed upon the shaft *h*; *i* is the driving rigger; *k*, pillar of support; *l*, blocks of wood, with which the workman pushes the beet-roots against the revolving rasp; *m*, the chest for receiving the beet-pap; *n*, the wooden cover of the drum, lined with sheet iron. The drum should make 500 or 600 turns in the minute.

1940



1941



By the process of M. Schützenbach the manufacture may be carried on during the whole instead of during a few winter months. At Waghäusel, near Carlsruhe, this system is adopted. The beets having been washed are rapidly cut up into small pieces, and subjected to the drying heat of a coke-fire for six hours. They lose from 86 to 84 per cent. of their weight; the dried root may be kept without injury for many months, and the sugar is extracted by infusion. At this colossal establishment, which in 1855 employed 3,000 people, and the building of which covered 12 acres of land, there were twenty infusing vessels, 12 to 14 feet deep and 7 wide. A cwt. of raw roots cost 7*d.*, and the dried root contained 46 to 47 per cent. of sugar; the capital employed was eighty millions of francs.

Whether the juice is extracted from fresh or dried beets the subsequent processes are the same. The juice, having been extracted either by infusion or by submitting the rasped pulp to hydraulic pressure, is placed in a shallow vessel, and mixed with as much milk of lime as renders it strongly alkaline, it is then boiled, generally by means of a copper coil heated by high-pressure steam. The excess of lime is removed by passing a stream of carbonic acid gas through the liquid. The gas is generally produced by forcing a stream of air through an enclosed coke-fire. The liquid is next filtered through cloth concentrated to a specific gravity of 25° B., filtered through animal-charcoal, and treated in all respects similarly to ordinary cane-sugar in a refinery. Though the vacuum-pan is employed in most beet-root establishments, there are some manufacturers who continue to evaporate in open vessels.

The large amount of water which has to be removed in the concentration of beet-root syrups involves the use of so much fuel that to economise it an ingenious apparatus has been constructed by M. Cail of Paris. The principle adopted is to use the steam generated from the ebullition of liquid in one vessel for boiling another, the steam from which in like manner boils a third.

The cultivation of the sugar-beet, so largely conducted on the Continent, has been introduced into this country. See Dr. Voelcker's paper 'On the Cultivation of Sugar-beet in England,' *Journ. Soc. Arts*, March 10, 1871.

In 1873 the total production of beet-root sugar in Europe amounted to 1,142,896 tons.

Maple-sugar.—The manufacture of sugar from the juice of a species of maple-tree, which grows spontaneously in many parts of North America, appears to have been first attempted about 1752, by some of the farmers of New England.

The sugar maple, the *Acer saccharinum* of Linnæus, thrives especially in the States of New York and Pennsylvania, and yields a larger proportion of sugar than that which grows upon the Ohio. It is found sometimes in thickets, but more usually interspersed among other trees. It is supposed to arrive at perfection in 40 years.

The extraction of maple-sugar is a great resource to the inhabitants of districts far removed from the sea, and the process is very simple. After selecting a spot among surrounding maple-trees, a shed is erected, called the *sugar-camp*, to protect the boilers and the operators from the vicissitudes of the weather. One or more augers, three-fourths of an inch in diameter; small troughs for receiving the sap; tubes of elder or sumach, 8 or 10 inches long, laid open through two-thirds of their length, and corresponding in size to the auger-bits; pails for emptying the troughs, and carrying the sap to the camp; boilers capable of boiling 15 or 16 gallons; moulds for receiving the syrup inspissated to the proper consistency for concreting into a loaf of sugar; and, lastly, hatchets to cut and cleave the fuel, are the principal utensils requisite for this manufacture. February and the beginning of March is the sugar-season.

The trees are bored obliquely from below upwards, at 18 or 20 inches above the ground, with two holes 4 or 5 inches asunder. Care must be taken that the auger penetrates no more than half an inch into the alburnum, or white bark; as experience has proved that a greater discharge of sap takes place at this depth than at any other. It is also advisable to perforate in the south face of the trunk.

The trough, which contains 2 to 3 gallons, and is made commonly of white pine, is set on the ground at the foot of each tree, to receive the sap which flows through the two tubes inserted into the holes made with the auger; it is collected together daily, and carried to the camp, where it is poured into casks, out of which the boilers are supplied. In every case it ought to be boiled within the course of two or three days from flowing out of the tree, as it is liable to run quickly into fermentation, if the weather become mild. The evaporation is urged by an active fire, with careful skimming during the boiling; and the pot is continually replenished with more sap, till a large body has assumed a syrupy consistency. It is then allowed to cool, and passed through a woollen cloth, to free it from impurities.

The syrup is transferred into a boiler to three-fourths of its capacity, and it is urged with a brisk fire, till it acquires the requisite consistency for being poured into the moulds or troughs prepared to receive it. This point is ascertained, as usual, by its exhibiting a granular aspect, when a few drops are drawn out into a thread between the finger and thumb. If in the course of the last boiling, the liquor froth up considerably, a small bit of butter or fat is thrown into it. After the molasses has been drained from the concreted loaves, the sugar is not at all deliquescent, like equally brown sugar from the cane. Maple-sugar is in taste equally agreeable with cane-sugar, and it sweetens as well. When refined it is equally fair with the loaf-sugar of Europe.

The period during which the trees discharge their juices is limited to about six weeks. Towards the end of the flow, it is less abundant, less saccharine, and more difficult to be crystallised.

The total production of maple-sugar has been estimated at 45 millions of pounds.

Potato-sugar.—The manufacture of sugar from starch derived from potatoes, from woody matter, and from rags, can be effected by treating them with sulphuric acid and heat; but the process, interesting though it is, is rarely if ever adopted at present, as the sugar is inferior in quality to that obtained from the cane, and is dearer in price.

The specific gravity of cane and beet-root sugar is 1·577, not 1·6065 as given by Berzelius and others; that of starch-sugar, in crystalline tufts, is 1·39, or perhaps 1·40, as it varies a little with its state of dryness. At 1·342 syrup of the cane contains seventy per cent. of sugar; at the same density syrup of starch-sugar contains seventy-five and a half per cent. of concrete matter, dried at 260° Fahr., and, therefore, freed from the ten per cent. of water, which it contains in the granular state. Thus, another distinction is obtained between the two sugars in the relative densities of their solutions, at like saccharine contents, per cent.

One of the most important considerations for a sugar-refiner is to furnish himself amply with bone-charcoal of the best quality, and to devote unsparing attention to the process of revivification. The theory of the action of bone-charcoal upon solutions of raw sugar and other coloured liquids need not be discussed here. See CHARCOAL.

The following Table contains the average results of many analyses made by Dr. Wallace of Glasgow, of several kinds of raw sugar as imported into Greenock and Glasgow, and of the different products of a Greenock sugar-house:—

	West India	Beet	Date	Lumps	Pieces	Bastards	Green syrup	Golden syrup	Molasses	Treacle
Cane-sugar . . .	94·4	95·7	95·4	97·3	87·7	68·3	62·7	39·6	48·0	32·5
Fruit-sugar . . .	2·2	0·3	1·8	0·5	6·0	15·0	8·0	33·0	18·0	37·2
Extractive and colouring-matter . .	0·3	0·4	0·1	...	0·5	1·2	0·6	2·8	1·5	3·5
Ash	0·2	1·6	0·2	0·2	0·8	1·5	1·0	2·5	1·4	3·4
Insoluble matter . .	0·1	...	1·7	...	...	...	...	...	...	...
Water	2·8	2·0	0·8	2·0	5·0	14·0	27·7	22·7	31·1	23·4
Total . .	100	100	100	100	100	100	100	100	100	100

Sugar *Imported* in 1873:—

	Class	Cwts.	Value £	Duty s.	d.
Refined or sugar equal in quality, and sugar-candy		2,273,490	3,847,271	3	0 per cwt.
Unrefined sugar	1st	810,934	—	2	10 „
„	2nd	3,871,492	—	2	8 „
„	3rd	3,913,725	—	2	5 „
„	4th	5,654,177	—	2	0 „
Total unrefined of all kinds . .		14,241,328	17,066,026		

	Cwts.	£
Glucose, liquid or vegetable syrup .	36,306	43,373
Molasses	520,315	245,766

Sugar *Imported* in 1874:—

	Cwts.	Value £
Refined and Candy . .	2,617,861	4,098,638
Unrefined	14,216,728	15,901,046
Molasses	339,352	181,544

Export of sugar, refined and candy, in 1874:—

930,729 cwts.; Value, 1,227,164*l.*

SUGAR OF LEAD, properly *Acetate of Lead* (*Acetate de plomb; Sel de Saturne,* Fr.; *Essigsaures Bleioxyd, Bleizucker,* Ger.), is prepared by dissolving pure litharge, with heat, in strong vinegar, made of malt, wood, or wine, till the acid be saturated. A copper boiler, rendered negatively electrical by soldering a strap of lead within it, is the best adapted to this process on the great scale. 325 parts of finely ground and sifted oxide of lead require 575 parts of strong acetic acid, of spec. grav. 7° Beaumé, for neutralisation, and afford 960 parts of crystallised sugar of lead. The oxide should be gradually sprinkled into the moderately hot vinegar, with constant stirring, to prevent adhesion to the bottom; and when the proper quantity is dissolved, the solution may be weakened with some of the washings of a preceding process, to dilute the acetate, after which the whole should be heated to the boiling point, and allowed to cool slowly in order to settle. The limpid solution is to be drawn off by a syphon, concentrated by boiling to the density of 32° B., taking care that there be always a faint excess of acid, to prevent the possibility of any basic salt being formed, which would interfere with the formation of regular crystals. Should the concentrated liquor be coloured, it may be whitened by filtration through granular bone-black.

Stoneware vessels, with salt-glaze, answer best for crystallisers. Their edges should be smeared with candle-grease, to prevent the salt creeping over them by *efflorescent vegetation.* The crystals are to be drained, and dried in a stove-room very slightly heated. It deserves remark, that linen, mats, wood, and paper, imbued with sugar of lead, and strongly dried, readily take fire, and burn away like tinder. When the mother-waters cease to afford good crystals, they should be decomposed by carbonate of soda, or by lime skilfully applied, when a carbonate or an oxide will be obtained, fit for treating with fresh vinegar. The supernatant acetate of soda may be employed for the extraction of pure acetic acid.

A main point in the preparation of sugar of lead is to use a strong acid; otherwise much time and acid are wasted in concentrating the solution. This salt crystallises in colourless, transparent, four- and six-sided prisms, from a moderately concentrated solution; but from a stronger solution, in small needles, which have a yellow cast if the acid has been slightly impure. It has no smell, a sweetish astringent metallic taste, a specific gravity of 2·345; it effloresces slightly in a dry atmosphere, and when heated above 212° Fahr. it froths up and loses all its water of crystallisation, together with some acetic acid, falling into a powder which passes slowly in the air into carbonate of lead. If heated to 536° Fahr. it is entirely liquid, and at a higher temperature is decomposed, disengaging acetic and carbonic acids, and some acetone; the residue consisting of very finely divided and very combustible metallic lead. The crystals of acetate of lead dissolve in 1½ time their weight of water at 60° Fahr., but in much less of boiling water, and in 8 parts of alcohol. The solution feebly reddens litmus-paper, although it imparts a green colour to syrup of violets. The constituents of the normal salt are, 58·71 oxide of lead, 27·08 acetic acid, and 14·21 water, in 100, or $PbO,C^4H^3O^3 + 3HO$ [$\mathbf{Pb(C^2H^3O^2)^2 + 3H^2O}$].

Acetate of lead is much used in calico-printing. It is poisonous, and ought to be prepared and handled with attention to this circumstance.

Four subacetates of lead are generally acknowledged to exist, viz.:—

Sesquibasic acetate. This is obtained by heating the neutral acetate in a capsule till the fused mass becomes white and porous; this is then dissolved in water and evaporated, when on cooling pearly laminæ separate; they are soluble in water and alcohol, and the solution possesses an alkaline reaction.

Dibasic acetate. This salt, when in solution, is known as *Goulard's extract,* and is formed by boiling together a solution of the neutral acetate and an equivalent quantity of pure litharge (oxide of lead). In the solid state it is crystalline.

Tribasic acetate. This salt is the most stable of the subsalts. It is obtained in the crystalline state, by leaving to itself a cold saturated solution of the neutral acetate, to which one-fifth of its volume of caustic ammonia has been added. It may also be made by digesting 7 parts of pure litharge with a solution containing 6 parts of the crystallised neutral acetate. It forms long silky needles, which are very soluble in water, but insoluble in alcohol. Carbonic acid transmitted through the solution precipitates the excess of oxide of lead, in the state of carbonate; a process long since described by Thénard, for making white lead.

Hexbasic acetate. This subsalt is obtained by boiling any of the other acetates with an excess of litharge. It is a precipitate, which, when examined by the microscope, presents a crystalline aspect. It is slightly soluble in boiling water, from which, in cooling, white silky needles are deposited. This salt is frequently found in commercial white lead. The solutions of subacetates are rapidly decomposed by the carbonic acid of the atmosphere.

SUINT. Quite a recent instance of improved economy is found in the treatment of the wool of sheep. It has been ascertained that sheep derive from the soil upon which they pasture a considerable amount of potash, which, after it has circulated in the blood, is secreted from the skin with the sweat, and remains, generally in connection with this, attached to the wool. Chevreul discovered, some time ago, that this peculiar mixture, known by the French as *Suint*, constitutes not less than one-third the weight of the raw merino fleece, from which it is easily removed by immersion in cold water. In ordinary wools the suint is less, the amount being about 15 per cent. of the raw fleece. Formerly it was considered as a kind of soap, mainly for the reason that the wool, besides this sometimes contained about 8 per cent, or a not inconsiderable quantity of fat. This fat, however, is usually combined with earthy matters, mostly with lime, and consequently forms a soap which is very insoluble. The soluble suint is a natural salt (sudorate of potash) arising from the combination of potash with a peculiar animal acid, of which little is known. Especial effort has lately been directed to suint, in order to obtain as much as possible of the potash eliminated from the animal, and a special industry has been established in various portions of the great French wool district, such as Rheims, Elbœuf, &c.

A company purchases from the wool-raiser the solution of the suint obtained by rinsing the wool in cold water, the price paid for it being higher in proportion as it is more concentrated. As a general thing it is maintained that a fleece weighing nine pounds contains 20 ounces of suint, which should contain about one-third part, or six to seven ounces of potash, although not more than five and one-half ounces, are perhaps directly available.

In the wool manufactories of the towns just referred to, there are nearly 60,000,000 pounds of wool washed annually, the yield of about 6,750,000 sheep. This quantity should contain over 3,000,000 pounds of pure potash. Thus the water in which the wool is washed, and which was formerly thrown away, is made to yield a product adding appreciably to the value of the wool itself, and more than covering the cost of its treatment. It is, of course, not an easy matter to utilise the solution of suint on a large scale; but, wherever the work is carried on by the wholesale, as it is in connection with all great manufacturing establishments, it will undoubtedly become a regular part of the process of manufacture.

SULPHATE OF ALUMINA AND POTASSA is common alum. See Alum.

SULPHATE OF BARYTA is the mineral called Heavy-Spar. See Baryta, Sulphate of.

SULPHATE OF COPPER, *Roman or Blue Vitriol* (*Kupfervitriol*, Ger.), $CuO.SO^3$ (**$CuSO^4$**), is a salt composed of sulphuric acid and oxide of copper, and may be formed by boiling the concentrated acid upon the metal, in an iron pot. It is, however, a natural product of many copper mines, from which it flows out in the form of a blue water, being the result of the infiltration of water over copper pyrites, which has become oxygenated by long exposure to the air in subterranean excavations. The liquid is concentrated by heat in copper vessels, and then set aside to crystallise. The salt forms in oblique four-sided tables, of a fine blue colour; has a spec. gravity of 2·104; an acerb, disagreeable, metallic taste; and, when swallowed, it causes violent vomiting. It becomes of a pale dirty blue, and effloresces slightly, on long exposure to the air; when moderately heated, it loses 36 per cent. of water, and falls into a whitish powder. It dissolves in 4 parts of water at 60°, and in 2 of boiling water, but not in alcohol; the solution has an acid reaction upon litmus-paper. When strongly ignited, the acid flies off, and the black oxide of copper remains. The constituents of crystallised sulphate of copper are oxide, 31·80; acid, 32·14; and water, 36·06. Its chief employment in this country is in dyeing, and for preparing certain green pigments. (See Scheele's and Schweinfurth Green.) In France, as well as in England, the farmers sprinkle a weak solution of it upon their grains and seeds before sowing them, to prevent them being attacked by birds and insects. See Copper.

SULPHATE OF IRON, *Green vitriol*, *Copperas* (*Couperose verte*, Fr.; *Eisenvitriol*, *Schwefelsaures Eisenoxydul*, Ger.), $FeO.SO^3$ (**$FeSO^4$**), is a compound of sulphuric acid and protoxide of iron; hence called, by chemists, the protosulphate; consisting of 26·10 of protoxide of iron, 29·90 of sulphuric acid, and 44·00 of water, in 100 parts. It may be prepared by dissolving iron to saturation in dilute sulphuric acid, evaporating the solution till a pellicle forms upon its surface, and setting it aside to crystallise. The copperas of commerce is made in a much cheaper way, by stratifying the pyrites found in the coal-measures (*Vitriolkies* and *Strahlkies* of the Germans), upon a sloping puddled platform of stone, leaving the sulphide exposed to the weather, till, by the absorption of oxygen it effloresces; lixiviating with water the supersulphate of iron thus formed, saturating the excess of acid with plates of old iron, then evaporating and crystallising. The other pyrites, which occurs often crystallised, called by the Germans *Schwefelkies* or *Eisenkies*, must be deprived of a part of its sulphur by calcination before it acquires the property of absorbing oxygen from the atmosphere, and thereby passing from a bisulphide into a sulphate. Alum-schist very commonly contains pyrites, and affords, after being roasted and weather-worn, a considerable quantity of copperas, which must be carefully separated by crystallisation from the alum.

This liquor used formerly to be concentrated directly in leaden vessels; but the first stage of the operation, is now carried on in stone canals of considerable length, vaulted over with bricks, into which the liquor is admitted, and subjected at the surface to the action of flame and heated air, from a furnace of the reverberatory kind, constructed at one end, and discharging its smoke by a high chimney raised at the other. (See SODA MANUFACTURE.) Into this oblong trough, resting on dense clay, and rendered tight in the joints by water-cement, old iron is mixed with the liquor, to neutralise the excess of acid generated from the pyrites, as also to correct the tendency to superoxidation in copperas, which would injure the fine green colour of the crystals. After due concentration and saturation in this surface-evaporator, the solution is run off into leaden boilers, where it is brought to the proper density for affording regular crystals, which it does by slow cooling, in stone cisterns.

Copperas forms sea-green, transparent, rhomboïdal prisms, which are without smell, but have an astringent, acerb, inky taste; they speedily become yellowish-brown in the air, by peroxidation of the iron, and effloresce in a warm atmosphere; they dissolve in 1·43 parts of water at 60°, in 0·27 at 190°, and in their own water of crystallisation at a higher heat. This salt is extensively used in dyeing black, especially hats; in making ink, and Prussian-blue, for reducing indigo in the blue vat, in the China blue-dye, for making the German oil of vitriol, and in many chemical and medicinal preparations.

SULPHATE OF LIME. See ALABASTER; GYPSUM; SELENITE.

SULPHATE OF MAGNESIA. See EPSOM SALTS; MAGNESIA, SULPHATE OF.

SULPHATE OF MANGANESE is prepared on the great scale for the calico-printers, by exposing the peroxide of the metal and pit-coal ground together, and made into a paste with sulphuric acid, to a heat of 400° Fahr. On lixiviating the calcined mass, a solution of the salt is obtained, which is to be evaporated and crystallised. It forms pale amethyst-coloured prisms, which have an astringent bitter taste, dissolve in 2½ parts of water, and consist of—protoxide of manganese, 31·93; sulphuric acid, 35·87; and water, 32·20, in 100 parts.

SULPHATE OF MERCURY. See MERCURY.

SULPHATE OF POTASH. See POTASH.

SULPHATE OF SODA is commonly called *Glauber's salt*, from the name of the chemist who first prepared it. See SODA, SULPHATE OF.

SULPHATE OF ZINC, called also *White Vitriol*, is commonly prepared in the Hartz, by washing the calcined and effloresced sulphide of zinc or blende, on the same principle as green and blue vitriol are obtained from the sulphides of iron and copper. Pure sulphate of zinc made be made most readily by dissolving zinc in dilute sulphuric acid, evaporating and crystallising the solution. It forms prismatic crystals, which have an astringent, disagreeable, metallic taste; they effloresce in a dry air, dissolve in 2·3 parts of water at 60°, and consist of—oxide of zinc, 28·29; acid 28·18; water, 43·53. Sulphate of zinc is used for preparing drying oils for varnishes, and in the reserve or resist pastes of the calico-printer. See ZINC.

SULPHATES are saline compounds of sulphuric acid with oxidised bases. The minutest quantity of them present in any solution may be detected by the precipitate, insoluble in nitric or muriatic acid, which they afford with nitrate or chloride of barium. They are mostly insoluble in alcohol.

SULPHIDE OF CARBON. See CARBON, BISULPHIDE OF.

SULPHITES are a class of salts, consisting of sulphurous acid, combined in equivalent proportions with the oxidised bases.

SULPHUR, *Brimstone* (*Soufre*, Fr.; *Schwefel*, Ger.), is an elementary substance of great importance. It is abundantly distributed in nature, either in the free state or in combination with other elements. In the free state it is found in three different forms: 1st, as kidney-shaped lumps, disseminated through beds of tertiary and recent formations; 2nd, in calcareous formations of Miocene age, associated with gypsum and rock-salt: it is under these circumstances that it is principally found in the mines of Sicily, which supply nearly all the sulphur of commerce in Europe; 3rd, as sublimations around the mouths of volcanoes, where it is mixed with the scoriæ and lava. The solfataras of Guadaloupe and Pouzzales supply it in this state.

The sulphur mines of Sicily, of which the principal are situated near Cattolica, Girgenti, Licata, Caltanisetta, Caltascibetta, Centorbi, and Sommatino, supply immense quantities of sulphur. According to Signor Mottura, the present annual production of Sicily is about 160,000 tons. The Romagna, Spain, and Iceland likewise supply sulphur.

Sulphur is also found largely in nature in combination, as sulphuric acid, and with metals forming sulphides; these latter combinations are known as pyrites. See PYRITES.

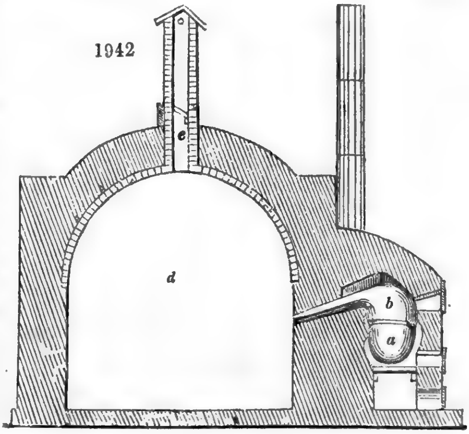
The process for the separation of the sulphur at the celebrated solfatara of

Pouzzales, near Naples, where the sulphur is condensed in considerable quantities amongst the gravel collected in the circle which forms the interior of the crater, is conducted as follows: the mixture of sulphur and gravel is dug up and submitted to distillation to extract the sulphur, and the gravel is returned to its original place, and in the course of about thirty years is again so rich in sulphur as to serve for the same process again. The distillation is effected in the following manner:—Ten earthen pots, of about a yard in height, and 4½ gallons imperial in capacity, bulging in the middle, are ranged in a furnace called a gallery; five being set on the one side, and five on the other. These are so distributed in the body of the walls of the gallery, that their belly projects partly without and partly within, while their top rises out of the vault of the roof. The pots are filled with lumps of the sulphur ore of the size of the fist; their tops are closed with earthenware lids, and from their shoulder proceeds a pipe of about 2 inches diameter, which bends down, and enters into another covered pot, with a hole in its bottom, standing over a tub filled with water. On applying heat to the gallery, the sulphur melts, volatilises, and runs down in a liquid state into the tubs, where it congeals. When one operation is finished, the pots are re-charged, and the process is repeated.

The sulphur thus obtained is still more or less impure, and in this case can only be used in the manufacture of sulphuric acid; it is therefore subjected to another process of purification, which will now be described:—

Fig. 1942 represents one of the cast-iron retorts used at Marseilles for refining sulphur, wherein it is melted and converted into vapours, which are led into a large chamber for condensation. The body, *a*, of the retort is an iron pot, 3 feet in diameter outside, 22 inches deep, half an inch thick, which weighs 14 cwts., and receives a charge of 8 cwts. of crude sulphur. The grate is 8 inches under its bottom, whence the flame rises and plays round its sides. A cast-iron capital, *b*, being luted to the top, and covered with sand, the opening in front is shut with an iron plate. The chamber *d*, is 23 feet long, 11 feet wide, and 13 feet high, with walls 32 inches thick. In the roof, at each gable, valves or flap-doors, *e*, 10 inches square, are placed at the bottom of the chimney *c*. The cords for opening the valves are led down to the side of the furnace. The entrance to the chamber is shut with an iron door. In the wall opposite to the retorts, there are two apertures near the floor, for taking out the sulphur. Each of the two retorts belonging to a chamber is charged with 7½ or 8 cwts. of sulphur; but one is fired first, and with a gentle heat, lest the brimstone froth should overflow; but when the fumes begin to rise copiously, with a stronger flame. The distillation commences within an hour of kindling the fire, and is completed in six hours. Three hours after putting fire to the first retort, the second is in like manner set in operation.

1942



When the process of distillation is resumed, after having been some time suspended, explosions may be apprehended, from the presence of atmospheric air: to obviate the danger of which, the flap-doors must be opened every 10 minutes; but they should remain closed during the setting of the retorts, and the reflux of sulphurous fumes or acid should be carried off by a draught-hood over the retorts. The distillation is carried on without interruption during the week, the charges being repeated four times in the day. By the third day, the chamber acquires such a degree of heat as to preserve the sulphur in a liquid state; on the sixth, its temperature becoming nearly 300° Fahr., gives the sulphur a dark hue, on which account the furnace is allowed to cool on the Sunday. The fittest distilling temperature is about 248°. The sulphur is drawn off through two iron pipes cast in the iron doors of the orifices on the side of the chamber opposite to the furnace. The iron stoppers being taken out of the mouths of the pipes, the sulphur is allowed to run along an iron spout placed over red-hot charcoal, into the appropriate wooden moulds.

Other forms of apparatus have been used of late years in Italy for the extraction of sulphur. The furnace most generally used is known as the *calcarone*, and consists of a circular wall of masonry, within which the ore is piled up. Steam at high pressure has also been applied to the fusion of the sulphur. See a paper by M. Pirckhey, entitled, 'Des Divers Procédés en usuage en Italie pour l'Extraction du Soufre de ses Minerais,' *Bull. d. l. Soc. de l'Ind. Min.* 1873.

According to Signor Parodi, there are now (1874) 250 sulphur mines in Sicily. The ore yields from 15 to 40 per cent. of sulphur, but the extraction is so wasteful that an average of only 14 per cent. is obtained.

In some places sulphur is obtained from the sulphides of iron and copper. In Saxony and Bohemia, they are introduced into large earthenware pipes, which traverse a furnace-gallery; and the sulphur exhaled flows into pipes filled with cold water on the outside of the furnace: 900 parts of sulphide afford from 100 to 150 parts of sulphur, and a residuum of protosulphide.

Pyrites, as a bisulphide, consisting of 45·5 parts of iron and 54·5 of sulphur, may, by proper chemical means, be made to give off one-half of its sulphur, or about 27 per cent.

The great disadvantage in the sulphur prepared from pyrites is, that some of the pyrites contain a large quantity of arsenic, and the sulphur thus obtained from them generally contains sulphide of arsenic, hence the sulphuric acid made from it would contain arsenic, and thus be unfitted for many purposes of the arts; though a tolerably good sulphuric acid may be made directly from the combustion of pyrites, instead of sulphur, in the lead-chambers. See PYRITES.

Sulphur occurs in commerce in two different forms, viz. solid, or in powder: the former is generally in sticks, and is called *lump*, *roll*, or *stick* sulphur; and the latter as *sublimed* or *flowers of sulphur*; and also the kind principally used in medicine, as *precipitated sulphur* or *milk of sulphur*. These different forms are caused by the different modes of preparation; if the sulphur be sublimed into large chambers, which are kept cool during the operation, the product will appear as a powder (*sublimed* or *flowers of sulphur*); but if the chamber be allowed to get hot, the sulphur melts, and is run off into moulds, and forms the lump sulphur. The washing of the sublimed sulphur is to remove any sulphurous or sulphuric acid, which it generally contains when taken from the chamber. The *precipitated sulphur* is formed by boiling ordinary sulphur with lime and water; the sulphur enters into combination with the lime, forming a sulphide of calcium and hyposulphite of lime, which dissolve in the water; to the filtered liquid hydrochloric acid is added, which unites with the lime and precipitates the sulphur. The sulphur thus precipitated is of a pale yellow colour, and when first precipitated will pass through a filter with the water, just as if it were in solution, from the fact of its being so finely divided. Some manufacturers use sulphuric acid instead of hydrochloric acid in this process, and therefore the milk of sulphur found in the shops is generally largely contaminated with sulphate of lime, feels gritty between the teeth, and sparkles when looked at in one direction.

Ordinary sulphur may be crystalline or amorphous; it is capable of crystallising in two different forms, and is hence said to be *dimorphous*. One form is that of acute rhombic octahedrons, belonging to the prismatic system, which is the principal form assumed by native sulphur, and may be obtained artificially by the spontaneous evaporation of a solution of sulphur in bisulphide of carbon; the second form is that of acute rhombic prisms, belonging to the oblique system, which is obtained by fusing sulphur in a crucible, and, when partly cooled, breaking the crust which is formed on the top, and pouring out the part which still remains liquid, when the part which has become solid will remain in long crystals. These crystals differ not only in shape, but also in specific gravity; the octahedral crystals having a specific gravity of 2·045, and the prisms a specific gravity of 1·982. The red tint, so common in the crystals of Sicily, and of volcanic districts, has been ascribed by some mineralogists to the presence of realgar, and by others to iron; but Stromeyer has found the sublimed orange-red sulphur of Vulcano, one of the Lipari Islands, to result from a natural combination of sulphur and selenium.

Sulphur also presents another peculiarity. At all ordinary temperatures it is solid, but it melts at 232° Fahr., and at this temperature it is as fluid as water; if the heat be now gradually raised, it will become thicker and thicker until, between 430° and 480° Fahr., it is so tenacious that the vessel containing it may be inverted for a moment without losing any of its contents; if while in this state it is cooled suddenly, as by pouring it into cold water it will remain for many hours perfectly soft and flexible, and may be drawn out into threads; it now presents none of the appearances of sulphur, and is called *amorphous sulphur*. After some time, however, it regains its former properties, becoming brittle and crystalline, and may be restored still more rapidly to its original state by melting and slow cooling. If the temperature be still raised above 480° Fahr., the sulphur between this and the boiling-point 792° Fahr., becomes again perfectly liquid. When heated in contact with the air, sulphur ignites and burns with a pale blue flame, generating sulphurous acid gas, which is employed to bleach woollen and silken goods; to disinfect vitiated air, though for this purpose it is greatly inferior to chlorine; to kill mites, moths, and other destructive insects in zoological collections; and to counteract too rapid fermentation in wine-vats, &c.

Sulphur has a slight odour, and scarcely any taste. It is a very bad conductor of heat; and a lump of sulphur, even by the heat of the hand, will produce a crackling sound, and often break in pieces. It is a bad conductor of electricity, and by friction becomes strongly charged with electricity, which is of the negative kind. Sulphur is insoluble in water and alcohol; but is dissolved by oil of turpentine and the fatty oils: the best solvent of it, however, is bisulphide of carbon. In its chemical relations it is allied to oxygen, &c. It has been known from the most remote ages, and from its kindling at a moderate temperature is employed for readily procuring fire, and lighting by its flame other bodies less combustible.

Sulphur is also employed for cementing iron bars into stones; for taking impressions from seals and cameos, for which purpose it is kept previously melted for some time to give the casts an appearance of bronze. Its principal uses, however, are for the manufactures of gunpowder and sulphuric acid.

There is another form in which sulphur is sometimes known, and this is what is termed *horse brimstone* or *black sulphur*. It is the dregs of the subliming pot after the purification of sulphur, and often contains large quantities of arsenic.

The purity of sulphur may be known by its being completely volatilisable, and by being soluble in bisulphide of carbon; any earthy impurities would in either case remain behind.

SULPHURATION is the process by which woollen, silk, and cotton goods are exposed to the vapours of burning sulphur—sulphurous acid gas.

Sulphuring-rooms are sometimes constructed upon a great scale, in which blankets, shawls, and woollen clothes may be suspended freely upon poles or cords. The floor should be flagged with a sloping pavement, to favour the drainage of the water that drops down from the moistened cloth. The iron or stoneware vessels, in which the sulphur is burned, are set in the corners of the apartment. They should be increased in number according to the dimensions of the place, and distributed uniformly over it. The windows and the entrance door must be made to shut hermetically close. In the lower part of the door there should be a small opening, with a sliding shutter, which may be raised or lowered by the mechanism of a cord passing over a pulley.

SULPHURETTED HYDROGEN, or *Hydrosulphuric acid.* Sulphur does not unite directly with hydrogen when in the free state, but when the sulphides of those metals which dissolve in dilute acids with liberation of hydrogen are treated with the same acids, they are dissolved, and the hydrogen, as soon as liberated, unites with the sulphur of the sulphide, and is evolved as sulphuretted hydrogen. Sulphide of iron is the most general substance that is used for this purpose; the action goes on without the application of heat. The following equation represents the decomposition:

$$\mathrm{FeS + HO.SO^3 = FeO.SO^3 + HS} \quad (\mathbf{FeS + H^2SO^4 = FeSO^4 + H^2S}).$$

This substance does not yield the gas in the pure state; hence, when its purity is an object, it is obtained by the action of hydrochloric acid on tersulphide of antimony; in this case the gas is only liberated by the application of heat:

$$\mathrm{SbS^3 + 3HCl = SbCl^3 + 3HS} \quad (\mathbf{Sb^2S^3 + 6HCl = Sb^2Cl^6 + 3H^2S}).$$

The sulphide of iron may easily be prepared by projecting into a red-hot crucible a mixture of 2½ parts of sulphur and 4 parts of iron-filings, or borings of cast iron, and excluding the air as much as possible. Another process is to raise a bar of iron to a white heat, and then rub it with a lump of sulphur, over a vessel of water, when the drops of fused sulphide fall into the water.

Sulphuretted hydrogen, at ordinary temperatures, is a colourless gas, possessing a most disgusting odour. It is liberated by many vegetable and animal substances in a state of decay. Its density is 1·171, and it contains 1 part of hydrogen and 16 parts of sulphur by weight. It possesses the properties of an acid, and its solution in water reddens litmus-paper.

At a temperature of 50°, and under a pressure of 17 atmospheres, it is condensed to a highly limpid colourless liquid, of specific gravity 0·9, and when cooled to $-122°$ solidifies, and is then a white crystalline translucent substance, heavier than the liquid. In the undiluted state this gas is very suffocating: the best antidote is a little chlorine, which decomposes it immediately, liberating the sulphur:

$$\mathrm{HS + Cl = HCl + S} \quad (\mathbf{H^2S + Cl^2 = 2HCl + S}).$$

It is very soluble in water, that liquid dissolving 2½ times its bulk of the gas; the solution quickly becomes milky from the deposition of sulphur, the oxygen of the air uniting with the hydrogen:

$$HS + O = HO + S \quad (\mathbf{H^2S} + \mathbf{O} = \mathbf{H^2O} + \mathbf{S}).$$

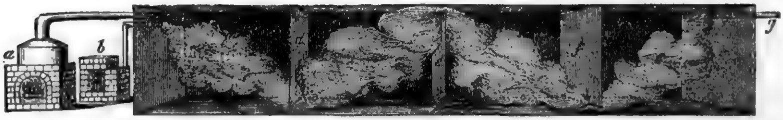
The principal use of sulphuretted hydrogen is in the laboratory for the separation of certain metals from their solutions. Being much heavier than air, it can be poured from one vessel to another.

SULPHURIC ACID, *Vitriolic Acid*, or *Oil of Vitriol*. (*Acid sulfurique*, Fr.; *Schwefelsäure*, Ger.). This important liquid now forms an extensive article of manufacture. It was formerly prepared by the distillation of sulphate of iron or green vitriol, from which it received its name of *oil of vitriol* or *vitriolic acid*. It was subsequently found that it might be produced by the combustion of sulphur, and the ultimate further oxidation of the sulphurous acid, thus obtained, by the means of nitric acid; and from time to time improvements have been made in the process, until it is now almost, perhaps entirely, perfect.

In the first place the sulphur is burnt on suitable hearths, and the sulphurous acid produced is carried by flues, together with some nitrous and nitric acids, generated in the same furnace from a mixture of nitre and sulphuric acid, into the large leaden chambers, into which steam and air are also admitted; here the different gases react on each other, and the sulphurous acid becomes converted into sulphuric acid, which falls into the dilute sulphuric acid which is placed in the bottom of the chamber, which thereby becomes stronger, and, when of sufficient strength, is drawn off, and concentrated first in leaden vessels, and finally in vessels of platinum.

The place where the sulphur is burnt is a kind of furnace, but instead of the grate, there is a stone hearth or iron plate, called the *sole*. The nitre-pot or pan is of cast iron. In it the nitre is decomposed by the sulphuric acid, and it is placed in the burner when required. The leaden chamber has the form of a parallelopiped, the size varying with the amount of work required to be done. To produce 10 tons of oil of vitriol weekly, the chamber should have a capacity of 35,000 cubic feet; or a length of 187 feet, a breadth of 12½ feet, and a height of 15 feet. The bottom is covered to the depth of 3 or 4 inches with water acidulated with sulphuric acid. These leaden chambers are sometimes divided into 3 or 4 compartments by leaden curtains placed in them, which cause the more perfect mixture of the gases. *Fig.* 1943 is a drawing of one thus divided, taken from Pereira's 'Materia Medica.'

1943



OIL OF VITRIOL-CHAMBER.

a. Steam-boiler.
b. Section of furnace of burner.
d and *f*. Leaden curtains from the roof of the chamber to within six inches of the floor.
e. Leaden curtains rising from the floor to within six inches of the roof.
g. Leaden conduit or vent-tube for the discharge of uncondensible gases. It should communicate with a tall chimney to carry off these gases, and to occasion a slight draught through the chamber.

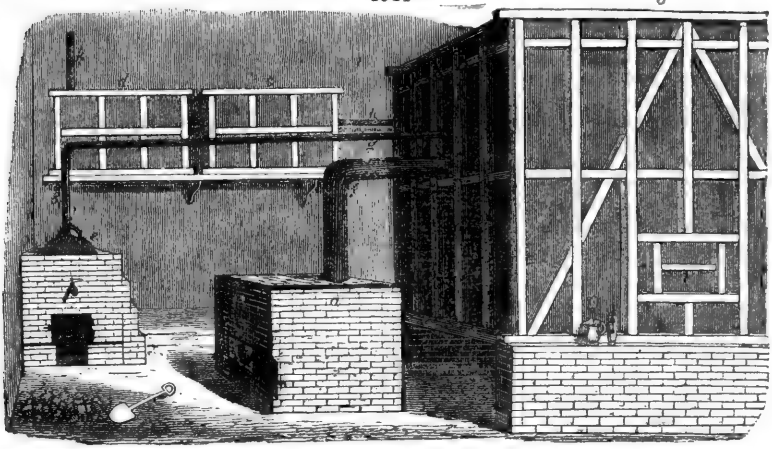
These curtains serve to detain the vapours, and cause them to advance in a gradual manner through the chamber, so that generally the whole of the sulphurous acid is converted into sulphuric acid and deposited in the water at the bottom before it reaches the discharge pipes; but as such is not always the case, there are sometimes smaller chambers, also containing water, appended to the larger, from which they receive the escaping gases before they are allowed to pass out into the air, and thus prevent loss. These smaller chambers are seen in *fig.* 1944 *c*, *d*, also taken from Pereira's 'Materia Medica.'

Another method for preventing this loss was contrived by M. Gay-Lussac, and made the subject of a patent in this country by his agent, M. Sautter. It consists in causing the waste gas of the vitriol-chamber to ascend through the *chemical cascade* of M. Clément Desormes, and to encounter there a stream of sulphuric acid of specific gravity 1·750. The nitrous acid gas, which is in a well-regulated chamber always slightly redundant, is perfectly absorbed by the said sulphuric acid; which, thus impregnated, is made to trickle down through another cascade, up through which passes a current of sulphurous acid, from the combustion of sulphur in a little adjoining chamber. The condensed nitrous acid gas is thereby immediately transformed into nitrous gas (binoxide of nitrogen), which is transmitted from the second cascade into the large vitriol-chamber, and there exercises its well-known reaction upon its aëriform contents. The economy thus effected in the sulphuric-acid manufacture is such that for 100 parts of sulphur, 3 of nitrate of soda will suffice, instead of 9 or 10 as usually consumed.

The flue or waste-pipe serves to carry off the residual gas, which should contain nothing but the nitrogen of the atmosphere, which has been introduced.

There are at least two plans at present in use for burning the sulphur continuously in the oven. In the one, the sulphur is laid on the hearth (or rather on the flat hearth in the separate oven, above described,) and is kindled by a slight fire placed under it; which fire, however, is allowed to go out after the first day, because the oven becomes by that time sufficiently heated by the sulphur-flames to carry on the subsequent combustion. Upon the hearth, an iron tripod is set, supporting, a few inches above it a hemispherical cast-iron bowl (basin) charged with nitre and its decomposing portion of strong sulphuric acid. In the other plan, 12 parts of bruised sulphur and 1 of nitre, are mixed in a leaden trough on the floor with 1 of strong sulphuric acid, and the mixture is shovelled through the sliding iron door upon the hot hearth. The successive charges of sulphur are proportioned, of course, to the size of the chamber. In one of the largest, which is 120 feet long, 20 broad, and 16 high, 12 cwts. are burned in the course of 24 hours, divided into 6 charges, every fourth hour, of 2 cwts. each. In chambers of one-sixth greater capacity, containing 1,400 meters cube, 1 ton of sulphur is burned in 24 hours. This immense production was first introduced at Chaunay and Dieuze, under the management of M. Clément Desormes. The bottom of the chamber should be covered at first with a thin stratum of sulphuric acid, of sp. gr. 1·07, which decomposes hyponitric acid into oxygen and binoxide of nitrogen; but not with mere water, which would absorb the hyponitric acid vapours, and withdraw them from their sphere of action. The crystalline compound, described below, is often formed, and is deposited, at low temperatures, in a crust of considerable thickness (from one-half to one inch) on the sides of the chamber, so as to render the process inoperative. A circumstance of this kind occurred, in a very striking manner, during winter, in a manufacture of oil of vitriol in Russia; and it has sometimes occurred, to a moderate

1944



Oil of Vitriol Manufactory.

a. Sulphur burner or furnace.

b. First leaden chamber. In the manufactory from which the above sketch was made this chamber was 70 feet long, 20 feet wide, and 20 feet high; but the size varies considerably in different establishments.

c. Second } smaller leaden chambers.
d. Third }

e. Steam-boiler.

f. Flue pipe or chimney of the furnace.

g. Steam-pipe.

h. The flue or pipe conveying the residual gas from the first to the second leaden chamber.

i. Pipe conveying the gas, not absorbed in the first and second chamber, into the third.

k. Flue or waste pipe.

l. Manhole, by which the workmen enter the chamber when the process is not going on.

m. Pipe for withdrawing a small portion of sulphuric acid from the chamber, in order to obtain its sp. gr. by the hydrometer.

extent, in Scotland. It is called, at Marseilles, the *maladie des chambres.* It may be certainly prevented, by maintaining the interior of the chamber, by a jet of steam, at a temperature of 100° Fahr. When these crystals fall into the dilute acid at the bottom, they are decomposed with a violent effervescence, and a hissing gurgling noise, somewhat like that of a tun of beer in brisk fermentation.

The introduction of steam is a modern invention, which has vastly facilitated and increased the production of oil of vitriol. It serves, by powerful agitation, not only to mix the different gaseous molecules intimately together, but to impel them against each other, and thus bring them within the sphere of their mutual chemical attraction. This is its mechanical effect. Its chemical agency is still more important. By supplying moisture at every point of the immense included space, it determines the formation of hydrous sulphuric acid, from the compound of nitric, hyponitric, sulphurous, and dry sulphuric acids.

Besides the process here described, which is called the *continuous* process, there was another formerly adopted, called the *intermittent* process. This was also carried on in large leaden chambers, but instead of a continuous stream of air, as passes into the chambers, through the furnace by the continuous process, the chambers were opened now and then to introduce fresh atmospheric air. This process is, however, now abandoned.

By the continuous method, sulphuric acid may be currently obtained in the chambers, of the specific gravity 1·35, or 1·45 at most; but when stronger, it absorbs and retains permanently much nitrous acid gas; by the intermittent process, however, it may be obtained as dense as 1·550, or even 1·620; hence where fuel is high priced, as near Paris, this method recommended itself by economy in the concentration of the acid. In Great Britain, and even in most parts of France, however, where time, workmen's wages, and interest of capital, are the paramount considerations, manufacturers do not find it for their interest in general to raise the density of the acid in the chambers above 1·400, or at most 1·500; as the further increase goes on at a retarded rate, and its concentration from 1·400 to 1·600, in leaden pans, costs very little.

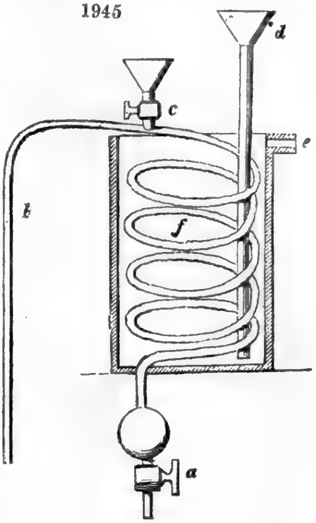
For many purposes in the arts the acid, as it is taken from the leaden chambers, is quite strong enough, and is employed under the name of 'Chamber Acid.'

At about the specific gravity of 1·35, in Great Britain, the liquid of the chambers is run off by the syphon above described, into a leaden gutter or spout, which discharges it into a series of rectangular vessels made of large sheets of lead of 12 or 14 lbs., to the square foot, simply folded up at the angles into 8 or 10 inches deep, resting upon a grate made of a pretty close row of wrought-iron bars of considerable strength, under which the flame of a furnace plays. Where coals are very cheap, each pan may have a separate fire; but where they are somewhat dear, the flame, after passing under the lowest pan of the range, which contains the strongest acid (at about 1·600), proceeds upwards with a slight slope to heat the pans of weaker acid, which, as it concentrates, is gradually run down by syphons to replenish the lower pans, in proportion as their aqueous matter is dissipated. The three or four pans constituting the range are thus placed in a straight line, but each at a different level, terrace-like.

When the acid has thereby acquired the density of 1·650, or 1·700 at most, it must be removed from the leaden evaporators, because when of greater strength it would begin to corrode them; and it is transferred into leaden coolers, or run through a long refrigeratory worm-pipe, surrounded by cold water. In this state it is introduced into glass or platinum retorts, to undergo a final concentration, up to the specific gravity of 1·842, or even occasionally 1·845. When glass retorts are used, they are set in a long sand-bath over a gallery-furnace, resting on fire-tiles, under which a powerful flame plays; and as the flue gradually ascends from the fireplace near to which it is most distant from the tiles, to the remoter end, the heat acts with tolerable equality on the first and last retort in the range. When platinum stills are employed, they are fitted into the inside of cast-iron pots, which protect the thin bottom and sides of the precious metal. The fire being applied directly to the iron, causes a safe, rapid, and economical concentration of the acid. The iron pots, with their platinum interior, filled with concentrated boiling-hot oil of vitriol, are lifted out of the fire-seat by tackle, and let down into a cistern of cold water, to effect the speedy refrigeration of the acid, and facilitate its transvasion into carboys packed in osier baskets lined with straw. Sometimes, however, the acid is cooled by running it slowly off through a long platinum syphon, surrounded by another pipe filled with cold water. *Fig.* 1945 shows a contrivance for this purpose.

The under stopcock *a* being shut, and the leg *b* being plunged to nearly the bottom of the still, the worm is to be filled with concentrated cold acid through the funnel *c*. If that stopcock is now shut, and *a* opened, the acid will flow out in such quantity as to rarefy the small portion of air in the upper part of the pipe *b*, sufficiently to make the hot acid rise up over the bend, and set the syphon in action. The flow of the fluid is to be so regulated by the stopcock *a*, that it may be greatly cooled in its passage by the surrounding cold water in the vessel *f*, which may be replenished by means of the tube and funnel *d*, and overflow at *e*.

1945



The platinum retort admits of from four to six operations in a day, when it is well mounted and managed. It has a platinum capital, furnished with a short neck, which conducts the disengaged vapours into a lead-worm of condensation; and the liquid thus obtained is returned into the lead-pans. Great care must be taken to prevent any particles of lead from getting into the platinum vessel, since at the temperature of boiling sulphuric acid, the lead unites with the precious metal, and thus causes holes in the retort. These must be repaired by soldering on a plate of platinum with gold.

Sanitary motives alone induced the makers of soda to condense their waste hydrochloric acid in the first instance; though they now discover its worth as a means of manufacturing chloride of lime, and would not again return to the nuisance-creating system if they might.

The complicated changes which take place in the leaden chambers during the conversion of the sulphurous acid into sulphuric acid, were first traced by M. Clément Desormes. He showed that hyponitric acid and sulphurous acid gases when mixed react on each other through the intervention of moisture; that there thence resulted a crystalline combination of sulphuric acid, binoxide of nitrogen, and water. That this crystalline compound was instantly destroyed by more water, with the separation of the sulphuric acid in a liquid state, and the disengagement of binoxide of nitrogen; that this gas re-constituted hyponitric acid at the expense of the atmospheric oxygen of the leaden chamber, and thus brought matters to their primary condition. From this point, starting again, the particles of sulphur in the sulphurous acid, through the agency of water, became fully oxygenated by the hyponitric acid, and fell down in heavy drops of sulphuric acid, while the binoxide of nitrogen derived from the hyponitric acid, had again recourse to the air for its lost dose of oxygen. This beautiful interchange of the oxygenous principle was found to go on, in their experiments, till either the sulphurous acid or oxygen in the air was exhausted.

They verified this proposition, with regard to what occurs in sulphuric-acid chambers, by mixing in a crystal globe the three substances, binoxide of nitrogen, sulphurous acid, and atmospheric air. The immediate production of red vapours indicated the transformation of the binoxide into hyponitric acid gas; and now the introduction of a very little water caused the proper *reaction*, for opaque vapours arose, which deposited white star-formed crystals on the surface of the glass. The gases were once more transparent, and colourless; but another addition of water melted these crystals with effervescence, when ruddy vapours appeared. In this manner the phenomena were made to alternate, till the oxygen of the included air was expended, or all the sulphurous acid was converted into sulphuric. The residuary gases were found to be hyponitric acid gas, and nitrogen without sulphurous acid gas; while unctuous sulphuric acid bedewed the inner surface of the globe. Hence, they justly concluded their new theory of the manufacture of oil of vitriol to be demonstrated.

There are some points in the manufacture of sulphuric acid which require attention.

1st. If the heat in the sulphur-furnace is too high, or when there is not a sufficient supply of air, some sulphur sublimes, and is condensed in the chamber, and at last falls into the sulphuric acid at the bottom of the chamber. By this means, not only is less sulphuric acid produced, but the sulphuric acid, when drawn from the chamber, contains some sulphur in suspension: in this case it must be allowed to stand, so as to deposit the sulphur, which may be collected, washed, dried, and again used. If the sulphur were not removed before concentrating, it would, at the temperature requisite for evaporation, decompose the sulphuric acid, with the escape of sulphurous acid gas, and hence much sulphuric acid would be lost. The reaction that would take place is represented by the following equation:—

$$\underbrace{2(HO.SO^3)}_{\text{Sulphuric acid.}} + \underbrace{S}_{\text{Sulphur.}} = \underbrace{3SO^2}_{\text{Sulphurous acid gas.}} + \underbrace{2HO.}_{\text{Water.}}$$

$$\mathbf{2H^2SO^4} + \mathbf{S} = \mathbf{3SO^2} + \mathbf{2H^2O.}$$

2nd. If there is not a sufficient quantity of steam admitted into the chamber, the solid compound of sulphuric acid and binoxide of nitrogen, above mentioned, would be formed on the sides of the chamber, and thus remove the oxidising agent from action, and hence a large quantity of sulphurous acid would escape by the waste-pipe unchanged.

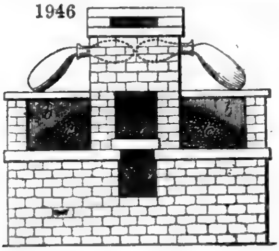
3rd. A deficiency of nitric acid in the chamber also causes great loss; the sulphurous acid, as in the former case, escaping unoxidised.

The first of these three subjects was counteracted by M. Grovelle, who, taking advantage of an idea put forth by M. Clément Desormes, constructed a furnace for burning the sulphur, so as to have a double current of air. He substituted for the sole of the furnace some parallel bars of iron, on which were placed cast-iron pans or boxes, bound together, but leaving intervals for the entrance of air between each: these were filled with sulphur, which was then ignited, and thus a plentiful supply of air was constantly kept up.

The reactions which take place in the sulphuric-acid chamber have recently been studied by Mr. H. A. Smith, who concludes, contrary to generally-received opinions, that under certain circumstances action can take place between dry sulphurous acid and nitric-acid gases without the intervention of steam. He believes that the best form of chamber should be long and not high, having, in fact, the following dimensions: length 150 feet, width 95 to 30 feet, and height 10 to 12 feet. The temperature should be kept as nearly as possible at 200° Fahr., and in starting the chamber he recommends that sulphuric acid should be run on the bottom in preference to water. See 'The Chemistry of Sulphuric Acid Manufacture,' by H. A. Smith, 1873.

Fuming, or Nordhausen Sulphuric Acid. At Nordhausen and other parts of Saxony, sulphuric acid continues to be made upon the old plan. This consists in first subjecting sulphate of iron, or green vitriol, to a gentle heat, by which it is deprived of its water of crystallisation; it is then distilled in earthenware, tubular, or pear-shaped retorts, of which a large number are placed in a gallery-furnace. *Fig.* 1946 shows the fireplace; *a b b*, chamber on each side of the fireplace, for depriving the green vitrol, *c c*, of its water.

1946



To these retorts are adapted earthenware receivers, into which some ordinary sulphuric acid is previously placed, to condense all the anhydrous sulphuric acid which comes over. The heat is raised gradually, and at last the retorts are subjected to an intense heat, which is kept up for several hours.

Some sulphurous acid gas escapes, arising from the decomposition of some of the sulphuric acid of the sulphate by the oxide of iron, and nothing remains in the retorts but sesquioxide of iron.

Anhydrous Sulphuric Acid, or Sulphuric Anhydride. This is most easily obtained by subjecting the Nordhausen sulphuric acid to a gentle heat in a glass retort, to which is adapted a dry receiver placed in ice. White fumes of anhydrous sulphuric acid come over and are condensed in the receiver. Care must be taken to avoid water coming into contact with it, as it unites with it with some violence.

It is best to have a receiver which can be hermetically sealed as soon as the operation is completed.

Properties of the different Sulphuric Acids.

Anhydrous Sulphuric Acid, or *Sulphuric Anhydride.* (SO^3.) This is a white crystalline body, very much resembling asbestos in appearance. Exposed to the air, some of it absorbs moisture, and the rest flies off in white fumes. Dropped into water it produces a hissing noise, just like red-hot iron, and in large quantities causes explosion. It melts at 66° Fahr., and boils at about 120° Fahr. The sp. gr. of the liquid, at 78° Fahr., is 1·97 (*Pereira*), and that of its vapour 3·0 (*Mitscherlich*). It does not present acid properties unless moisture be present.

Nordhausen Sulphuric Acid. $HO.SO^3,SO^3$ ($\mathbf{H^2SO^4SO^3}$). This is an oily liquid, generally of a brown colour (from some organic matter), which gives off white fumes of anhydrous sulphuric acid when exposed to the air. Its sp. gr. is about 1·9. It is imported in stoneware bottles, having a stoneware screw for a stopper. It is probably only a solution of anhydrous sulphuric acid in ordinary oil of vitriol, as, after being subjected to a gentle heat, nothing remains but the latter. It often contains several impurities. It is principally used for dissolving indigo, which it does completely without destroying the colour.

Ordinary Sulphuric Acid, or Oil of Vitriol. $HO.SO^3$ ($\mathbf{H^2SO^4}$). Sp. gr. 1·845. This is, when pure, a colourless, transparent, highly acrid, and most powerfully corrosive liquid. It is a very strong mineral acid, one drop being sufficient to communicate the power of reddening litmus-paper to a gallon of water, and produces an ulcer if placed upon the skin. It chars most organic substances. This depends upon its attraction for water, which is so great that, when exposed in an open saucer, it imbibes one-third of its weight from the atmosphere in twenty-four hours, and fully six times its weight in a few months. Hence it should be kept excluded from the air. If four parts, by weight, of the strongest acid be suddenly mixed with one part of water, both being at 50° Fahr., the temperature will rise to 300° Fahr.; while, on the other hand, if four parts of ice be mixed with one of sulphuric acid, they immediately liquefy and sink the thermometer to 4° below zero. In this last case the heat, that would otherwise have been given off, has been employed in liquefying the ice. Upon the mixing the acid and water they both suffer condensation, the dilute acid, thus formed, occupying less space than the two separately, and hence the evolution of heat. This affinity for water, which sulphuric acid possesses, is often made use of for evaporating liquids at a low temperature. The liquid is placed in a dish over another dish containing sulphuric acid, and both are placed under the receiver of an air-pump. Such is the rapidity with which the evaporation is carried on, that if a small vessel of water be so placed it will speedily be frozen. Sulphuric acid is decomposed by several substances when boiled with them; such are most organic substances, sulphur, phosphorus, and several of the metals, as mercury, copper, tin, &c.

Sulphuric acid of sp. gr. 1·845, boils at about 620° Fahr., and may be distilled unchanged. This is the best way to obtain it pure. It is a most powerful poison. If swallowed in its concentrated state, even a small quantity, it acts so powerfully on the throat and stomach as to cause intolerable agony and speedy death. Watery diluents, mixed with chalk or magnesia, are the readiest antidotes.

Ordinary oil of vitriol generally contains some sulphate of lead, which will be precipitated, as a white powder by dilution with water; since so much of it is made from iron pyrites at the present day, it contains arsenic in variable quantities. The best test for sulphuric acid, either free or combined, as soluble salts, is a salt of barium. An extremely small quantity of sulphuric acid, or a soluble salt of it, is thus easily detected by the greyish-white cloud of sulphate of baryta which it occasions in the solution. 100 parts of the concentrated acid are neutralised by 143 parts of dry pure carbonate of potash, and by 110 of dry pure carbonate of soda.

The presence of saline impurities in sulphuric acid may be determined by evaporating a certain quantity to dryness in a platinum capsule. If more than 2 grains of residue remain out of 500 of acid it may be considered impure.

Of all the acids, the sulphuric is most extensively used in the arts, and is, in fact, the primary agent for obtaining almost all the others, by disengaging them from their saline combinations. In this way nitric, hydrochloric, tartaric, acetic, and many other acids, are procured. It is employed in the direct formation of alum, of the sulphates of copper, zinc, potassa, soda; in that of sulphuric ether, of sugar by the saccharification of starch, and in the preparation of phosphorus, &c. It serves also for opening the pores of skins in tanning, for clearing the surfaces of metals, for determining the nature of several salts by the acid characters that are disengaged, &c.

The Table on next page, which shows the quantity of concentrated and dry sulphuric acid in 100 parts of dilute, at different densities, was constructed by Dr. Ure.

SULPHUROUS ACID. (SO^2.) Sulphur fumigations are mentioned by Homer, but sulphurous acid, of which these are composed, was first accurately examined by Stahl, Scheele, and Priestley, and afterwards by Gay-Lussac and Berzelius.

It escapes from the earth, in the gaseous form, in the vicinity of volcanoes, but is always prepared artificially when required for use, and for this purpose several processes are employed.

1. By heating copper-cuttings, or mercury, with concentrated sulphuric acid in a glass flask, sulphate of copper, or persulphate of mercury, and sulphurous acid are formed:

$$\underbrace{Cu}_{\text{Copper.}} + \underbrace{2(HO.SO^3)}_{\text{Sulphuric acid.}} = \underbrace{CuO.SO^3}_{\text{Sulphate of copper.}} + \underbrace{SO^2}_{\text{Sulphurous acid.}} + \underbrace{2HO.}_{\text{Water.}}$$

$$\mathbf{Cu + 2H^2SO^4 = CuSO^4 + SO^2 + 2H^2O.}$$

Liquid	Sp. grav.	Dry	Liquid	Sp. grav.	Dry	Liquid	Sp. grav.	Dry
100	1·8460	81·44	66	1·5503	53·82	32	1·2334	26·09
99	1·8438	80·72	65	1·5390	53·00	31	1·2260	25·28
98	1·8415	79·90	64	1·5280	52·18	30	1·2184	24·46
97	1·8391	79·99	63	1·5170	51·37	29	1·2108	23·65
96	1·8366	78·28	62	1·5066	50·55	28	1·2032	22·83
95	1·8340	77·46	61	1·4960	49·74	27	1·1956	22·01
94	1·8288	76·65	60	1·4860	48·92	26	1·1876	21·20
93	1·8235	75·83	59	1·4760	48·11	25	1·1792	20·38
92	1·8181	72·02	58	1·4660	47·29	24	1·1706	19·57
91	1·8126	74·20	57	1·4560	46·48	23	1·1626	18·75
90	1·8070	73·39	56	1·4460	45·66	22	1·1549	17·94
89	1·7986	72·57	55	1·4360	44·85	21	1·1480	17·12
88	1·7901	71·75	54	1·4365	44·03	20	1·1410	16·31
87	1·7815	70·94	53	1·4170	43·22	19	1·1330	15·49
86	1·7728	70·12	52	1·4073	42·40	18	1·1246	14·68
85	1·7640	69·31	51	1·3977	41·58	17	1·1165	13·86
84	1·7540	68·49	50	1·3884	40·77	16	1·1090	13·05
83	1·7425	67·68	49	1·3788	39·95	15	1·1019	12·13
82	1·7315	66·86	48	1·3697	39·14	14	1·0953	11·41
81	1·7200	66·05	47	1·3612	38·32	13	1·0887	10·60
80	1·7080	65·23	46	1·3530	37·51	12	1·0809	9·78
79	1·6972	64·42	45	1·3440	36·69	11	1·0743	8·97
78	1·6860	63·60	44	1·3345	35·88	10	1·0682	8·15
77	1·6744	62·78	43	1·3255	35·06	9	1·0614	7·34
76	1·6624	61·97	42	1·3165	34·25	8	1·0544	6·22
75	1·6500	61·15	41	1·3080	33·43	7	1·0477	5·71
74	1·6415	60·34	40	1·2999	32·61	6	1·0405	4·89
73	1·6321	59·52	39	1·2913	31·80	5	1·0336	4·08
72	1·6204	58·71	38	1·2826	30·98	4	1·0268	3·26
71	1·6090	57·89	37	1·2740	30·17	3	1·0206	2·446
70	1·5975	57·08	36	1·2654	29·35	2	1·0140	1·63
69	1·5868	56·25	35	1·2572	28·54	1	1·0074	0·1584
68	1·5760	55·45	34	1·2490	27·72			
67	1·5648	54·63	33	1·2409	26·91			

The sulphurous acid is passed through a wash-bottle, to remove any trace of sulphuric acid which may come over, and then through a tube containing chloride of calcium, if the gas be wanted dry; it may then be collected over mercury in the pneumatic trough, or by displacement of air; it cannot be collected over water, owing to its great solubility in that liquid.

2. By heating charcoal, or almost any organic substance, with concentrated sulphuric acid in the same apparatus as above; but in this case the sulphurous acid is contaminated with a large quantity of carbonic acid, which, however, does not interfere with it in many cases, as when employed in the manufacture of alkaline sulphites:

$$\underbrace{C}_{\text{Charcoal.}} + \underbrace{2(HO.SO^3)}_{\text{Sulphuric acid.}} = \underbrace{CO^2}_{\text{Carbonic acid.}} + \underbrace{2SO^2}_{\text{Sulphurous acid.}} + \underbrace{2HO.}_{\text{Water.}}$$

$$\mathbf{C + 2H^2SO^4 = CO^2 + 2SO^2 + 2H^2O.}$$

3. By the combustion of sulphur or iron pyrites in oxygen gas or in atmospheric air, and this is the process most generally employed on the large scale, as in the manufacture of sulphuric acid. See SULPHURIC ACID.

$$\underbrace{S}_{\text{Sulphur.}} + \underbrace{O^2}_{\text{Oxygen.}} = \underbrace{SO^2.}_{\text{Sulphurous acid.}}$$

Properties. At ordinary temperatures and atmospheric pressure sulphurous acid is a colourless, transparent gas, possessing the disagreeable odour so well known to those who have burnt a sulphur-match. It is neither combustible, nor a supporter of combustion, and is always the product obtained by burning sulphur in air. It is a weak acid, and is very soluble in water, that liquid at 60° Fahr. dissolving more than thirty times its volume of the gas; the solution of sulphurous acid, thus obtained, bleaches some vegetable colours, as well as the gas itself, viz. those of roses and violets, &c., but in most cases the colours may be restored by treating with a weak acid or alkali. It cannot be respired in the pure state, as it immediately causes spasm of the glottis; but if diluted with air and then breathed, it acts as a local irritant, exciting cough, pain, and a sense of dryness of the mouth and throat. Its sp. gr. is 2·2; 100 cubic inches weighing 68·69 grains. Its solution in water may be kept any time without change, as long as air is excluded, but when air gains access to it, it is gradually converted into sulphuric acid.

SULPHURS. Impressions taken by the goldsmiths of the sixteenth century from the engravings executed on plate, paxes, &c., and which they obtained by spreading a layer of melted sulphur on the face of the plate, producing a cast *in relief* of the lines engraved. Some few of these proofs exist in the British and Continental Museums, and are known as *sulphurs*. They are amongst the rarest specimens connected with the art of engraving.

SULPHYDROMETRY. The determination of sulphur.

SUMACH, or **SHUMACH.** A species of the genus *Rhus*, used in tanning. It is known also as *sumac* and *shumac*. It consists of the ground-leaves, foot-stalks, and young twigs of several varieties of plants, technically known as sumacs, but botanically belonging to the genus *Rhus* of the Natural Order *Anacardiaceæ*. The sumac of commerce is chiefly obtained from the *Rhus Coriaria*, in the following manner:—A short time before the blooming of the plant in June or July, the younger twigs are cut off, dried in the sun, next beaten, so as to detach the leaves and flower panicles, which are next coarsely ground up by means of millstones. The shrub just named is a native of Asia, but is cultivated in many parts of Europe, more especially in Sicily, Spain, Southern France, and Hungary. Sumac is also prepared from the *Rhus Cotinus*.

In the South of France a peculiar kind of sumac is prepared, and known locally as *redout* or *redou*. It is derived from the *Coriaria myrtifolia*, or tanner's-herb, which contains a violently poisonous substance.

The leaves of the *Arbutus Uva-ursi*, better known in pharmacy than in technology, are used as sumac in Dalecarlia, Sweden.

The following are the chief varieties of sumac known in the trade:—

Sicilian Sumac.—The most esteemed article, fetching always a high price,

Spanish Sumacs.—Exported from Malaga, Priego or Mohua, Valladolid.

Portuguese Sumacs.—From Oporto.

Italian Sumacs.

French Sumacs.

The articles are classified here according to their amount of tannin.

Imports in 1873.

	Tons	Value £
From Italy	11,806	183,037
„ Austrian Territories	1,304	16,017
„ Other countries	672	9,327
Total	13,782	208,381

SUNFLOWER OIL. See Oils.

SUNN consists of the fibre of the *Crotolaria juncea*, a totally different plant from the *Cannabis sativa*, from which hemp is obtained, Sunn is grown in various places of Hindostan. The strongest, whitest, and most durable species is produced at Comercolly. It is also known as *Bengal Hemp*.

SUNSTONE. A variety of felspar, of a pale yellowish colour, found in Siberia. It is almost perfectly transparent when viewed in one direction; but by reflected light it appears full of minute golden spangles. See Felspar.

SUPERPHOSPHATE, properly superphosphate of lime, much used as a manure. See Phosphates, and Manure.

SUSSEX MARBLE. Thin bands of shelly limestone, occurring here and there in the Weald Clay, especially in the upper part. This limestone is principally composed of the remains of freshwater snails, a species of *Paludina*, and it has been named Sussex marble, in consequence of its great development in that county. Although the stone is not remarkable for any particular beauty of colour, being generally of a uniform bluish or greyish-green tint, the sections of the chambers of the shells give it, when polished, a pleasing appearance, and it has, in consequence, been frequently made use of in former times in the construction of tombs and sepulchral monuments in many of our older churches.—H. W. B.

SWAGES. Tools employed in shaping metals.

SWALLOW, ESCULENT (*Hirundo esculenta*). These birds construct the edible nests which form so considerable a part of Chinese commerce. It is the *Larvet* of the Japanese, the *Salangana* of some writers on the Eastern Archipelago. The nests are made of a particular species of sea-weed (see ALGÆ), which the bird macerates and bruises before it employs the material in layers, so as to form the whitish gelatinous cup-shaped nests so much prized as delicacies by the Chinese.

SWANS'-DOWN. There is a production of 500,000 puffs made annually from about 7,000 swans'-down skins, imported into Britain.

SWEEP-WASHER is the person who extracts from the sweepings, potsherds, &c. of refineries of silver and gold, the small residuum of precious metal.

SWEETMEATS. Any article prepared chiefly with sugar is so called. A considerable number are described under CONFECTIONERY.

SYCAMORE. The wood of the *Acer pseudo-platanus*.

SYENITE is a crystalline rock, consisting of orthoclase-felspar and hornblende; but the term is also frequently applied to a mixture of hornblende, orthoclase, and quartz. It takes its name from the city of Syene, in the Thebaid, near the Cataracts of the Nile, but the rock there is not a true syenite. It is an excellent building-stone, and was imported from Egypt, by the Romans, for the architectural and statuary decorations of their capital. Hornblende is the characteristic ingredient, and serves to distinguish syenite from granite, with which it has been sometimes confounded. The Egyptian Syenite, containing but little hornblende, with a good deal of quartz and mica, approaches most nearly to granite. It is equally metalliferous with porphyry. In the island of Cyprus, it is rich in copper; and in Hungary, it contains many valuable gold and silver mines. Syenite forms a considerable part of the Criffle, a hill in Galloway. The so-called 'granites' of Leicestershire more nearly approach syenites. A careful study of the rocks of the Grooby, Markham, and Bardon Hill quarries, will show a gradual change of the granitic rock, through syenite, into a greenstone-porphyry. This stone is extensively used in the metropolis and other large towns for 'pitching' and paving. Much of the 'granite' of the Channel Islands, used in the metropolis for road-metal, is a syenite, or at least a hornblendic or syenitic granite.

SYLVANITE, or *Graphic Tellurium.* A valuable ore of gold and silver, found at Offenbanya in Transylvania, in narrow veins traversing porphyry, and at Gold Hill, North Carolina. Its analysis by Petz gave: silver, 11·47; gold, 21·97; tellurium, 39·97; lead, 0·25; copper, 0·76; antimony, 0·58 = total, 100·00.

SYLVINE. Chloride of potassium; a mineral formerly of great rarity, but found of late years in abundance among the deposits of potash-salts, overlying the rock-salt of Stassfurt in Prussian Saxony, and at Kalusez in Galicia. Sylvine is an important source of other salts of potassium.

SYMBOLS. Signs adopted by chemists to indicate the simple elements, or the combinations of them, forming a compound body. A symbolic language has been universally adopted by chemists, and the facilities it offers very strongly recommend it. The symbols H, O, S, C, stand respectively for hydrogen, oxygen, sulphur, and carbon; each elementary substance being represented by the initial letter of its Latin name. When the initial letter of any two elements are similar, as, for example, carbon, chlorine, and calcium—the first and third, or second letters of the name are taken, as Cl (Chlorine), Ca (Calcium). See ATOMIC WEIGHTS, for the symbols of all the known elements.

These symbols not only represent the element, but the relative quantities of it which enters into combination. This is, of course, an arbitrary, though convenient arrangement. The letters HO, for example, represent, not merely hydrogen and oxygen, but 1 part of hydrogen and 8 parts of oxygen, which in combination represents water. A figure placed on either of the right-hand corners of the symbol for any element indicates the number of atoms which enter into the combination spoken of, as HO^2 represents 2 atoms of oxygen combined with 1 atom of hydrogen—peroxide of hydrogen. A figure placed on the left hand doubles all that follows it up to the addition sign + or bracketed symbols: 2HO represents 2 atoms of water; KO, *kalium* or potassium and oxygen = potash; SO^2, sulphur and oxygen = sulphurous acid; KO,SO^3 represents sulphate of potash, but $KO,2SO^3$ indicates *Bi*-sulphate of potash.

A combination of symbols representing a compound body constitutes a *formula*.

SYNTHESIS is a Greek word, which signifies 'combination,' and is applied to the chemical action which unites dissimilar bodies into a uniform compound: as sulphuric acid and lime into gypsum; or chlorine and sodium into culinary salt.

SYRUP is a solution of sugar and water. Cane-juice, concentrated to a density of 1·300, forms a syrup which does not ferment in the transport home from the West Indies, and may be boiled and refined at one step into superior sugar-loaves.

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TABASHEER. A siliceous concoction resembling hydrophane, which is formed in the interior of the stem of the large Indian bamboo.

TABBINET. A delicate kind of tabby or watered silk, produced by passing the silk through engraved rolls.

TABBY. Watered silk; the effect being produced by subjecting the silk when damp to pressure.

TABBYING, or *Watering*, is the process of giving stuffs a wavy appearance by a peculiar manipulation with the calender.

TABULAR SPAR. A silicate of lime, known otherwise as *Wollastonite*.

TACAMAHAC is a resin obtained from the *Fagara octandra*, a tree which grows in Mexico and the West Indies. It occurs in yellowish pieces, of a strong smell, and a bitterish aromatic taste.

TAFFETY is a light silk fabric, with a considerable lustre or gloss.

TALC is a mineral of which several varieties are recognised, as :—

Foliated Talc. This, the purest crystalline talc, composed of easily separable folia, presenting light green, greenish-white, and white colours. This is often found massive, disseminated in plates, imitative, or crystallised in small six-sided tables. It is splendent, pearly, or semi-metallic, translucent, flexible, but not elastic. It yields to the nail ; spec. grav. 2·77. Before the blowpipe, it first whitens, and then fuses into an enamel globule. It consists of—silica, 62 ; magnesia, 27 ; alumina, 1·5 ; oxide of iron, 3·5 ; water, 6. Klaproth found 2½ per cent. of potash in it. It is found in beds of clay-slate and mica-slate, in Aberdeenshire, Banffshire, Perthshire, Salzburg, the Tyrol, and St. Gothard.

The substance used in sheets as a cover for gas-jets, although often called talc, is really mica.

Talcose Slate. A slaty rock of a greenish-grey colour ; it is massive, with tabular fragments, translucent on the edges, soft, with a white streak ; easily cut or broken, but is not flexible ; and has a greasy feel. It occurs in the same localities as the preceding. It is employed in the crayon-manufactures ; also as a crayon itself, by carpenters, tailors, and glaziers.

Indurated Talc. An impure slaty talc, with a nearly compact texture and of superior hardness to common talc.

Soapstone or *Steatite* (*Speckstein*, Ger.) ; coarse grey and greyish-green massive varieties, generally granular ; also of fine texture. The *Potstone*, or *Lapis ollaris*, includes the coarser granular specimens, of dark colour and more or less impure. Slabs of steatite are extensively used as fire-stones. It is often turned into ornamental articles. When ground it is used to diminish friction, and it was employed in the manufacture of some kinds of porcelain. Venetian talc is used for removing stains from woollen cloth. The fine varieties of talc, when coloured with the safflower, form a rouge for the toilet. See STEATITE.

TALLOW (*Suif*, Fr. ; *Talg*, Ger.), is the concrete fat of quadrupeds and man. That of the ox consists of 76 parts of stearine and 24 of oleine ; that of the sheep contains somewhat more stearine. See FAT and STEARINE.

Ox-tallow was alone used formerly, and our great supply was from Russia. Australia now, and America too, however, export to Europe a large quantity of mutton-tallow.

The drier the food upon which animals are fed the more solid is the tallow ; hence the Russian tallow is the best, the animals being fed for eight months of the year on dry fodder.

In the animal the tallow exists in separate globules, and the object of melting it out is to combine all these into one mass. The *rendering* of tallow, as it is termed, consists in cutting the fat into small pieces, and placing it in a pan over a naked fire. The heat is regulated, and the first action is the bursting of the cells ; these pour out their milky contents, which become clear gradually, as the water which it contains is evaporated.

Mechanical power is sometimes applied to aid in the rendering. The fat is placed under a millstone working on edge, and thus the cells are torn and crushed, and when this is once effected, the tallow separates with great ease at a moderate temperature. Dorrett employed weak sulphuric acid to act upon the tallow, by mixing this acid with boiling water, and retaining it after the fat has been placed within it, until the separation of the fatty matter is completed. Some admit steam to the melting mass, by which a larger quantity of tallow appears to be obtained. Tallow is generally so impure, that it has to be clarified by the candle-maker. This is effected by remelting the tallow, and mixing with it some substances which render insoluble the gelatinous matters, and precipitate the adventitious admixtures. See CANDLES and FAT.

Tallow and Stearine *Imported* in 1874:—

	Cwts.		£
From Russia	81,704	Value of	183,183
„ Argentine Republic	171,696	„	335,669
„ United States	440,421	„	894,862
„ Australia	282,293	„	535,101
„ Other countries	178,685	„	369,436
Total	1,154,799		2,318,251

TALLOW, MINERAL. See HATCHETTINE.

TALLOW, PINEY. See OILS.

TALMI GOLD. An alloy known also as 'Abyssinian gold;' it is much used for making imitation jewellery. Dr. C. Winkler says: 'The alloy is not galvanically gilt, but is plated, that is to say, a very thin sheet of gold is made to adhere to a yellow metal (in 100 parts—copper, 90·74; zinc, 8·33) by rolling the metals together and afterwards shaping, moulding, and chiselling it by means of steel tools, the amount of gold varying from 1·03 to 0·03 per cent.' Articles made of this alloy are said to wear really well. See ABYSSINIAN GOLD.

TAMBAC. See TOMBAC.

TAMPING is a term used by miners to express the filling up of the hole which they have bored in a rock, after the gunpowder for blasting has been placed in the bottom of the hole, with sand, the *débris* of the rock, or other matters. This, being beaten hard together, presents nearly as much resistance to the mechanical force of the powder, when exploded, as the rock itself. See MINING.

TANGLE. *Laminaria digitata.* See ALGÆ.

TANNENITE. An ore of bismuth. See BISMUTH.

TANNIN, or TANNIC ACID. (*Tannin*, Fr.; *Gertstoff*, Ger.) Under the name *tannin* were formerly included all those astringent principles which were capable of combining with the skins of animals to form leather, of precipitating gelatine or of forming bluish-black precipitates with the persalts of iron, and of yielding nearly insoluble compounds with some of the organic alkalis. But it has of late years been proved that there are several different kinds of tannic acid, most of which possess an acid reaction.

These principles are widely diffused in the vegetable kingdom; most of our forest trees, as the oak, elm, pines, firs; pear and plum trees contain it in variable quantities. It is also found in some fruits. Many shrubs, as the sumach and whortleberry, also contain it in great quantities, and on that account are largely used in dyeing and tanning. The roots of the tormentilla and bistort are also powerfully astringent from containing it. Coffee and tea also contain a modification of this principle. The astringent principle in all the above mentioned (except coffee) precipitate the persalts of iron bluish-black, or if a free acid be present the solution becomes dark green. The astringent principle of many vegetables precipitate the persalts of iron of a dark green; such are catechu, kino, &c. Some few plants contain another modification of this astringent principle, which precipitates the persalts of iron of a grey colour, such are rhatany, the common nettle, &c.

Many of these tannic acids have received names which refer to the plants from which they are obtained. The most important and best known of all these is the *gallo-tannic acid*, or that which is extracted from gall-nuts. There are also *querci-tannic acid*, from the oak; *moritannic acid*, or that from the fustic (*Morus tinctoria*), &c. See LEATHER.

The Table on the next page shows the quantity of extractive matter and tan in 100 parts of the several substances there named.

TANNING. (*Tanner*, Fr.; *Gärberei*, Ger.) This is the name given to the process employed for converting the skins of animals into leather, and is strictly a chemical process, consisting in the combination of the tannic acid of the different tanning materials with the gelatine of the skins.

Many attempts have been made to quicken the tanning process, but the leather so formed is generally of inferior quality and less durable. See LEATHER.

TANSY, *Tanacetum vulgare.* A plant common to Britain, growing in waste places; sometimes placed in beds to drive fleas from them. It is very bitter, and has an aromatic odour.

TANTALUM. This is an exceedingly rare substance, found in the minerals *tantalite* and *yttro-tantalite*. It was discovered by Mr. Hatchett, in a mineral

Substances	In 480, by Davy	In about 8 oz., by Biggins	In 100 parts, by Cadet de Gassincourt
White inner bark of old oak	72	..	21
Do. young oak	77	..	..
Do. Spanish chestnut	63	30	..
Do. Leicester willow	79	..	..
Coloured or middle bark of oak	19	..	..
Do. Spanish chestnut	14	..	..
Do. Leicester willow	16	..	..
Entire bark of oak	29	..	..
Do. Spanish chestnut	21	..	..
Do. Leicester willow	33	109	..
Do. elm	18	28	..
Do. common willow	11	boughs, 31	..
Sicilian sumach	78	158	..
Malaga sumach	79	..	..
Souchong tea	48	..	..
Green tea	41	..	..
Bombay catechu	261	..	..
Bengal catechu	231	..	..
Nut-galls	127	..	46
Bark of oak, cut in winter	..	0	..
Do. beech	..	31	..
Do. elder	..	41	..
Do. plum-tree	..	58	..
Bark of the trunk of willow	..	52	..
Do. sycamore	..	53	16
Bark of birch	..	54	..
Bark of cherry-tree	..	59	24
Do. sallow	..	59	..
Do. poplar	..	76	..
Do. hazel	..	79	..
Do. ash	..	82	..
Do. trunk of Span. chestnut	..	98	..
Do. smooth oak	..	104	..
Do. oak, cut in spring	..	108	..
Root of tormentil	..	..	46
Cornus sanguinea of Canada	..	..	44
Bark of alder	..	..	36
Do. apricot	..	..	32
Do. pomegranate	..	..	32
Do. Cornish cherry-tree	..	..	19
Do. weeping willow	..	..	16
Do. Bohemian olive	..	..	14
Do. tan shrub with myrtle-leaves	..	..	13
Do. Virginian sumach	..	..	10
Do. green oak	..	..	10
Do. service-tree	..	..	8
Do. rose chestnut of America	..	..	8
Do. rose chestnut	..	..	6
Do. rose chestnut of Carolina	..	..	6
Do. sumach of Carolina	..	..	5

brought from North America, and he called it, on that account, *Columbium.* Ekeberg discovered it in 1803 in the Swedish minerals, and, considering it a *new* metal, he called it *Tantalum.* Dr. Wollaston, in 1809, sought to show that Hatchett's *columbium* and Ekeberg's *tantalum* were one and the same substance; but H. Rose afterwards proved that they were distinct, and gave the name of *Niobium* to the former columbium.

Tantalum has not yet been applied to any commercial purpose.

TAP-CINDER. Puddling-furnace slag. This is a basic silicate of iron. Its general composition may be seen from the following analysis of tap-cinder from a Staffordshire furnace, by Dr. Percy: silica 23·86, protoxide of iron 39·83, peroxide of iron 23·75, protoxide of manganese 6·17, alumina 0·91, lime 0·28, sulphide of iron 0·62, phosphoric acid 6·42. See Iron and Slag.

TAP-HOLE. The hole in a puddling furnace, through which the slag flows out.

TAPESTRY is an ornamental figured textile fabric of worsted or silk, for lining the walls of apartments; of which the most famous is that of the Gobelins Royal Manufactory, near Paris. See Carpets, Lace, Textile Fabrics, and Weaving.

TAPIOCA. (*Manioc* and *Cipipa*, Fr.; *Weisse Sago*, Ger.) Tapioca is cassava-meal, which, while moist or damp, has been heated, for the purpose of drying it, on hot plates. By this treatment the starch-grains swell, many of them burst, and the whole agglomerates in small irregular masses or lumps. The drying to which it is subjected renders it difficult of solution. In boiling water it swells up, and forms a viscous jelly-like mass. See Starch.

TAQUA NUT. The vegetable ivory of commerce. See Ivory, Vegetable.

TAR, COAL. This substance, when properly distilled, is capable of yielding naphtha, a fixed oil, and pitch, the two former of which are vastly more valuable than tar. The relative proportion of these products is, however, very variable, according to the kind and quality of the tar employed. Thus tar from the condenser is more valuable for its products than the tar of the same coal taken from the hydraulic main, and again cannel coal-tar is always superior to common coal-tar. In general we may estimate the available amount of the volatile and fixed matters of coal somewhat in the following order:—

	Naphtha	Dead oil	Pitch
Common coal-tar	3	62	35
Ordinary cannel tar	9	60	31
Boghead cannel tar	15	67	18

Of these the naphtha is in large demand for the solution of caoutchouc, the lighting of lamps, and other purposes. The dead oil contains paraffine, and is an excellent lubricator for machinery: the uses of pitch need not be enumerated. See Aniline, Gas-Coal, Destructive Distillation, Naphtha, and Petroleum.

TAR, WOOD (*Goudron*, Fr.; *Theer*, Ger.), is the viscid, brown-black, resino-oleaginous compound, obtained by distilling wood in close vessels, or in ovens of a peculiar construction. *Stockholm tar*, *Archangel tar*, and *American tar* come into our markets. According to Reichenbach, tar contains the peculiar proximate principles, *paraffine*, *eupion*, *creosote*, *picamar*, *pittacal*, besides pyrogenous resin or *pyretine*, pyrogenous oil or *pyroleine*, and vinegar.

The Stockholm tar is regarded as the best; we have a description of the mode in which it is prepared, by Dr. Clarke, in his 'Travels in Scandinavia':—

'The situation most favourable to the process is in a forest near to a marsh or bog, because the roots of the fir, from which tar is principally extracted, are always most productive in such places. A conical cavity is then made in the ground (generally on the side of the bank or sloping hill), and the roots of the fir, together with logs and billets of the same, being neatly trussed in a stack of the same conical shape, are let into the cavity. The whole is then covered with a turf to prevent the volatile parts from being dissipated, which, by means of a heavy wooden mallet and wooden stamper, worked separately by two men, is beaten down and rendered as firm as possible about the wood. The stack of billets is then kindled, and a slow combustion of the fir takes place as in working charcoal. During this combustion the tar exudes, and a cast-iron pan being at the bottom of the funnel, with a spout which projects through the side of the bank, barrels are placed beneath this spout to collect the fluid as it comes away. As fast as the barrels are filled they are bunged and ready for immediate exportation.' Wood-tar is obtained as a secondary product in the manufacture of acetic acid, in the dry distillation of wood.

Tar *Imported* in 1873:—

	Barrels		£
From Russia	174,280	value	239,169
„ Sweden	12,670	„	19,127
„ Germany	9,558	„	13,094
„ United States of America . .	16,218	„	22,072
„ Other countries	2,604	„	3,670
Total .	215,330	„	297,132

Tar *Imported* in 1874:—

238,810 Barrels; value 269,749*l.*

TARE, or *Vetch.* A well known fodder-plant (*Vicia sativa*).

TARPAULIN (from *Tar*). Canvas imbued with tar, used to cover the hatchways of a ship to prevent rain or sea water from entering the hold, and for other purposes.

TARSAS. See Trass.

TARSIA (*Intarsiatura*, Ital.) A mosaic wood-work practised in Italy in the fifteenth century.

TARTAR (*Tartre*, Fr.; *Weinstein*, Ger.); called also *argal* or *argol*, is the crude bitartrate of potash, which exists in the juice of the grape, and is deposited from wines in their fermenting casks, being precipitated in proportion as the alcohol is formed, in consequence of its insolubility in that liquid. There are two sorts of argol known in commerce, the white and the red; the former, which is of a pale-pinkish colour, is the crust let fall by white wines; the latter is a dark red, from red wines.

The crude tartar is purified, or converted into cream of tartar, at Montpellier, by the following process:—

The argal having been ground under vertical millstones and sifted, one part of it is boiled with 15 of water in conical copper kettles tinned on the inside. As soon as it is dissolved, 3½ parts of ground pipe-clay are introduced. The solution, being well stirred and then settled, is drawn off into crystallising vessels to cool; the crystals found concreted on the sides and bottom are picked out, washed with water, and dried. The mother-water is employed upon a fresh portion of argol. The crystals of the first crop are re-dissolved, re-crystallised, and exposed upon stretched canvas to the sun and air to be bleached. The clay serves to abstract the colouring-matter. The crystals formed upon the surface are the whitest, whence the name 'cream of tartar' is derived.

Purified tartar, the bitartrate of potash, is thus obtained in hard clusters of small colourless crystals, which, examined by a lens, are seen to be transparent four-sided prisms. It has no smell, but a feebly acid taste; is unchangeable in the air, has a specific gravity of 1·953, dissolves in 16 parts of boiling water, and in 200 parts at 60° Fahr. It is insoluble in alcohol. It consists of 24·956 potash, 70·276 tartaric acid, and 4·768 water. See Argol; Potash, Bitartrate of.

TARTAR, CREAM OF. Acid tartrate of potash.

TARTAR EMETIC. Tartrate of potash and antimony, prepared by boiling teroxide of antimony in solution of cream of tartar.

TARTARIC ACID, (*Acide tartrique*, Fr.; *Weinsteinsäure*, Ger.) This is prepared by adding gradually to a boiling-hot solution of 100 parts of tartar (*bitartrate of potash*) in a large copper boiler, 26 parts of chalk (*carbonate of lime*) made into a smooth pap with water. A brisk effervescence ensues, from the disengagement of the carbonic acid of the chalk, while its base combines with the acid excess in the tartar, and forms an insoluble precipitate of tartrate of lime. The supernatant liquor, which is a solution of neutral tartrate of potash, must be drawn off by a syphon, and decomposed by a solution of chloride of calcium (muriate of lime). 28½ parts of the dry chloride are sufficient for 100 of tartar. The tartrate of lime, from both processes, is to be washed with water, drained, and then subjected in a leaden cistern to the action of 49 parts of sulphuric acid, previously diluted with 8 times its weight of water: 100 of dry tartrate take 75 of oil of vitriol. This mixture, after digestion for a few days, is converted into sulphate of lime and tartaric acid. The latter is to be separated from the former by decantation, filtration through canvas, and elutriation of the sulphate of lime upon the filter.

The clear acid is to be concentrated in leaden pans by a moderate heat, till it acquires the density of 40° B. (sp. gr. 1·38), and then it is run off, clear from any sediment, into leaden or stoneware vessels, which are set in a dry stove-room for it to crystallise. The crystals, being re-dissolved and re-crystallised, become colourless six-sided prisms. In decomposing the tartrate of lime, a very slight excess of sulphuric acid must be employed, because pure tartaric acid would dissolve any tartrate of lime that may escape decomposition. Bone-black, previously freed from its carbonate and phosphate of lime, by muriatic acid, is sometimes employed to bleach the coloured solutions of the first crystals. Tartaric acid contains nearly 9 per cent. of combined water. It is soluble in two parts of water at 60°, and in its own weight of boiling water. In its dry state, as it exists in the tartrate of lime or lead it consists of 36·8 of carbon, 3 of hydrogen, and 60·2 of oxygen. It is much employed in calico-printing, and for making sodaic powders.

In consequence of the great variation in the constituents of argol or rough tartar, the manufacture of tartaric acid is not nearly so simple as a first glance at its several processes might lead an inexperienced individual to suppose. The theory of preparing tartaric acid seems, indeed, a remarkably easy affair; and provided the materials operated upon were pure, or of uniform quality, no kind of manufacture could put on less the appearance of risk or speculation. But too many know, to their cost, with what ready facility the whole profit, and something more, of a large operation will occasionally ooze off through a variety of unknown channels, and present a sadly defective and truncated return of saleable produce. In fact, money is not unfrequently lost in this manufacture by very old and experienced makers. The differences in argol arise from the greater or smaller amount of tartrate of lime combined with the bitartrate of potash; these differences will, in a commercial way, amount to from 5 to 25 or even 30 per cent.; and herein resides a difficulty requiring more analytical skill and chemical knowledge than is commonly found amongst practical manufacturers. We will suppose that an argol has been purchased, containing by analysis 70 per cent. of bitartrate of potash, but also, though unknown to the purchaser, containing 20 per cent. of tartrate of lime. According to the process followed, this argol would be dosed with a definite proportion of chalk or carbonate of lime, so as to produce tartrate of lime with the extra tartaric acid of the supertartrate of potash. This tartrate of lime, being insoluble, would fall and mingle with the 20 per cent. already existing; but as in practice the quantity of sulphuric acid employed for subsequent decomposition of this tartrate of lime is proportioned to the amount of chalk originally employed, it follows that the tartrate of lime naturally present in the argol is left undecomposed, and comes to be regarded as sulphate of lime, to the great loss of the manufacturer, who probably finds his more intelligent neighbour able to buy as he buys, and yet capable of underselling him in the open market.

The composition of crystallised tartaric acid, appears to be represented by the formula $C^8H^6O^{12}$ (**$C^4H^6O^6$**). By the action of heat it loses 2HO (**H^2O**), and becomes anhydrous tartaric acid. Various metamorphoses have been stated to occur in tartaric acid upon exposing it to heat. Laurent, Gerhardt, and Pasteur have investigated this matter, and have given the names of *metatartaric acid* and *isotartaric acid* to two of the results. Another acid has been investigated by Arppe, the *pyrotartaric acid*. According to Millon and Reiset, the best mode of preparing it is to distil powdered tartaric acid with powdered pumice-stone. The aqueous is separated from the oily distillate by a wet filter, and evaporated at a gentle heat, till it commences to crystallise. The crystals are digested in nitric acid, and thus the pure pyrotartaric acid is obtained.

TARTRATES are bibasic salts, composed of tartaric acid and oxidised bases, in equivalent proportions. Some of the tartrates are employed in the arts, bitartrate of potash being used as a mordant in dyeing woollen fabrics. Tartrate of chromium is sometimes used in calico-printing, and the tartrate of potash and tin in wool-dyeing.

TASMANITE. A combustible mineral found in Tasmania. See Dysodile.

TAWING is the process of preparing the white skins of the sheep, doe, &c. See Leather.

TEA (*Thé*, Fr.; *Thee*, Ger.) *Thea*, the tea-plant, belongs to the natural order *Ternströmiaceæ*. Considerable discussion has taken place with reference to this important substance, some contending that green and black tea are the productions of two different plants, the *Thea viridis* producing the green tea, and the *Thea Bohea* the black tea. There is a third variety, the *Thea Assamensis*, or Assam tea, which appears to resemble both the others. Mr. Fortune appears to have proved that the green and black teas of commerce do not depend upon specific differences; but that in the northern tea districts of China the black and green teas are both obtained from the same species or variety, namely, the *Thea viridis*, while in the Canton tea districts both the varieties of tea are made from the *Thea Bohea*.

The quality of the tea depends much on the season when the leaves are picked, the mode in which it is prepared, as well as on the district in which it grows. Green tea, it is stated, is coloured by the application of an extract of indigo, of Prussian blue, and gypsum; and that the fine odour which renders the 'flowery' kinds remarkable is derived from the leaves of *Olea fragrans*, a species of camellia, and other similar plants.

To the black tea belong the varieties known as *Bohea, Congou, Campoi, Souchong, Caper*, and *Pekoe*. To the green tea, *Twankay, Hyson-skin, Hyson, Imperial*, and *Gunpowder*.

Brande, in his 'Manual of Pharmacy,' has given a table from which the following facts are extracted:—

100 parts of Tea		Soluble in water	Soluble in alcohol	Precipitated by jelly	Insoluble residue
Green Hyson —	Best .	41	44	31	56
„	Medium .	34	43	26	58
„	Lowest .	31	41	24	57
Black Souchong—	Best .	35	36	28	64
„	Medium .	37	35	28	63
„	Lowest .	35	31	23	65

The most remarkable products in tea are—1st. Tannin. 2nd. An essential oil to which it owes its aroma, and which has great influence on its commercial value. 3rd. A crystalline substance, very rich in nitrogen, *theine*, which is also met with in coffee (whence it is frequently termed *caffeine*).

Besides these three, M. Mulder extracted from tea eleven other substances, which are usually met with in all leaves. The same chemist found, in the various kinds of tea from China and Java, a little less than a half per cent. of their weight of theine. Dr. Stenhouse obtained from 1·36 to 0·98 theine from 100 parts of tea. On determining the nitrogen by M. Dumas's process, he obtained the following numbers:—

	Nitrogen in 100 parts tea dried at 230°
Pekoe tea	5·58
Gunpowder tea	6·15
Souchong tea	6·15
Assam tea	5·10

This amount of nitrogen is far more considerable than has been detected in any vegetable hitherto analysed.

The proportion of products soluble in hot water varies considerably, and depends chiefly upon the age of the leaf, which is younger, and consequently less liqueous, in the green than in the black tea. On an average, Stenhouse found in 100 parts

	Parts soluble in boiling water.
Dry black teas	43·2
Dry green teas	47·1
Black teas in their commercial state	38·4
Green teas do. do.	43·4

When an infusion of tea is evaporated to dryness, a chocolate-brown residue remains, which, when derived from green gunpowder, contains 5·35 per cent. of nitrogen; if from black souchong, 4·70 per cent. nitrogen.

The subacetate of lead throws down about half the soluble constituents contained in this infusion. The precipitate, which is of a more or less dark yellow, according to whether it is derived from green or black tea, contains the whole of the colouring-matter, the whole of the tannin, and a peculiar acid, which affords an insoluble salt of a light yellow colour with the subacetate of lead.

To determine the amount of theine, M. Mulder evaporates the infusion with caustic magnesia, and treats the residue with ether, which only dissolves out the theine. On modifying this process, Dr. Stenhouse has obtained the following quantities of theine from 100 parts of

Hyson	2·40
Another kind	2·56
Mixture in equal parts of gunpowder, hyson, imperial, caper, and pekoe	2·70
Gunpowder	4·1
Another kind	3·5

These quantities are far more considerable than have been obtained by M. Mulder; but, at the same time, they do not account for the total amount of nitrogen of the infusion in the state of theine, for the composition of theine being represented by the formula $C^8H^5N^2O^2$ ($\mathbf{C^8H^{10}N^4O^2}$), and this substance containing 29·0 per cent. of nitrogen, gunpowder tea should contain 7·4 and souchong 6·5 theine in 100 parts of these teas taken in their ordinary state, if no other nitrogenous substance accompanied the theine in the solution.

The portion of tea from which boiling water extracted no more soluble principle contained in 100 parts, dried at 230°, 4·46 nitrogen for the souchong, and 4·30 for the gunpowder. These quantities, added to those of the infusion, represent very nearly the nitrogen ascertained by analysis to exist in the entire leaf.

On boiling for some time the exhausted leaves in water containing $\frac{1}{10}$th of their weight of potash, a brown liquid is obtained, which affords, on the addition of dilute sulphuric or acetic acid, a considerable flocculent and brown precipitate, which contains 8·45 per cent. of nitrogen; the product of another preparation gave 9·93. Alcohol and ether remove from this precipitate about 30 per cent. of a green substance, which appears to contain a fat acid. This product is not pure after this treatment, for it is strongly coloured and contains pectic acid; nevertheless, that which contained 8·45 nitrogen afforded 11·35 of this element after being treated with alcohol and ether.

The Chinese method of making Black Tea.—In the first place, the youngest and most tender leaves are gathered; but when there are many hands and a great quantity of leaves to be collected, the people employed nip off with the forefinger and thumb the fine end of the branch with about four leaves on, and sometimes even more, if they look tender. These are all brought to the place where they are to be converted into tea; they are then put into a large, circular, open-worked bamboo basket, having a rim all round, two fingers broad. The leaves are thinly scattered on these baskets, and then placed in a framework of bamboo, in all appearance like the side of an Indian hut without grass, resting on posts, 2 feet from the ground, with an angle of about 25°. The baskets with leaves are put in this frame to dry in the sun, and are pushed up and brought down by a long bamboo with a circular piece of wood at the end. The leaves are permitted to dry about two hours, being occasionally turned; but the time required for this process depends on the heat of the sun. When they begin to have a slightly withered appearance, they are taken down and brought into the house, where they are placed on a frame to cool for half an hour. They are then put into smaller baskets of the same kind as the former, and placed on a stand. People are now employed to soften the leaves still more, by gently clapping them between their hands with their fingers and thumb extended, and tossing them up and letting them fall, for about five or ten minutes. They are then again put on the frame during half an hour, and brought down and clapped with the hands as before. This is done three successive times, until the leaves become to the touch like soft leather; the beating and putting away being said to give the tea the black colour and bitter flavour. After this the tea is put into hot cast-iron pans, which are fixed in a circular mud fireplace, so that the flame cannot ascend round the pan to incommode the operator. This pan is well heated by a straw or bamboo fire to a certain degree. About 2 lbs. of the leaves are then put into each hot pan, and spread in such a manner that all the leaves may get the same degree of heat. They are every now and then briskly turned with the naked hand, to prevent a leaf from being burned. When the leaves become inconveniently hot to the hand, they are quickly taken out and delivered to another man with a close-worked bamboo basket ready to receive them. A few leaves that may have been left behind are smartly brushed out with a bamboo broom; all this time a brisk fire is kept up under the pan. After the pan has been used in this manner three or four times, a bucket of cold water is thrown in, and a soft brick-bat and bamboo broom used, to give it a good scouring out; the water is thrown out of the pan by the brush on one side, the pan itself being never taken off. The leaves, all hot on the bamboo basket, are laid on a table that has a narrow rim on its back, to prevent these baskets from slipping off when pushed against it. The 2 lbs. of hot leaves are now divided into two or three parcels, and distributed to as many men, who stand up to the table with the leaves right before them, and each placing his legs close together; the leaves are next collected into a ball, which he gently grasps in his left hand, with the thumb extended, the fingers close together, and the hand resting on the little finger. The right hand must be extended in the same manner as the left, but with the palm turned downwards, resting on the top of the ball of tea-leaves. Both hands are now employed to roll and propel the ball along: the left hand pushing it on, and allowing it to revolve as it moves: the right hand also pushes it forward resting on it with some force, and keeping it down to express the juice which the leaves contain. The art lies here in giving the ball a circular motion, and permitting it to turn under and in the hand two or three whole revolutions, before the arms are extended to their full length, and drawing the ball of leaves quickly back without leaving a leaf behind, being rolled for about five minutes in this way. The ball of tea-leaves is from time to time gently and delicately opened with the fingers, lifted as high as the face, and then allowed to fall again. This is done two or three times, to separate the leaves; and afterwards the basket with the leaves is lifted up as often, and receives a circular shake to bring these towards the centre. The leaves are now taken back to the hot pans, and spread out in them as before, being again turned with the naked hand, and when hot taken out and rolled: after which they are put into the drying basket, and spread on a sieve which is in the centre of the basket, and the whole placed over a charcoal fire. The fire is very nicely regulated; there must not be the least smoke, and the charcoal should be well picked.

When the fire is lighted, it is fanned until it gets a fine red glare, and the smoke is all gone off; being every now and then stirred and the coals brought into the centre, so as to leave the outer edge low. When the leaves are put into the drying basket, they are gently separated by lifting them up with the fingers of both hands extended far apart, and allowing them to fall down again; they are placed 3 or 4 inches deep on the sieve, leaving a passage in the centre for the hot air to pass. Before it is put over the fire, the drying basket receives a smart slap with both hands in the act of lifting it up, which is done to shake down any leaves that might otherwise drop through the sieve, or to prevent them from falling into the fire and occasioning a smoke, which would affect and spoil the tea. This slap on the basket is invariably applied throughout the stages of the tea-manufacture. There is always a large basket underneath to receive the small leaves that fall, which are afterwards collected, dried, and added to the other tea; in no case are the baskets or sieves permitted to touch or remain on the ground, but always laid on a receiver with three legs. After the leaves have been half-dried in the drying basket, and while they are still soft, they are taken off the fire, and put into large open-worked baskets, and then put on the shelf, in order that the tea may improve in colour.

Next day the leaves are all sorted into large, middling, and small; sometimes there are four sorts. All these, the Chinese informed the writer, become so many different kinds of teas: the smallest leaves they called Pha-ho, the second Pow-chong, the third Suchong, and the fourth, or the largest leaves, Toy-chong. After this assortment they are again put on the sieve in the drying basket (taking great care not to mix the sorts), and on the fire, as on the preceding day; but now very little more than will cover the bottom of the sieve is put in at one time; the same care of the fire is taken as before, and the same precaution of tapping the drying basket every now and then. The tea is taken off the fire with the nicest care, for fear of any particle of the tea falling into it. Whenever the drying basket is taken off, it is put on the receiver, the sieve in the drying-basket taken out, the tea turned over, the sieve replaced, the tap given, and the basket placed again over the fire. As the tea becomes crisp, it is taken out and thrown into a large receiving basket, until all the quantity on hand has become alike dried and crisp; from which basket it is again removed into the drying basket, but now in much larger quantities. It is then piled up 8 and 10 inches high on the sieve in the drying basket; in the centre a small passage is left for the hot air to ascend; the fire that was before bright and clear has now ashes thrown on it to deaden its effect, and the shakings that have been collected are put on the top of all; the tap is given, and the basket with the greatest care is put over the fire. Another basket is placed over the whole, to throw back any heat that may ascend. Now and then it is taken off, and put on the receiver; the hands, with the fingers wide apart, are run down the sides of the basket to the sieve, and the tea gently turned over, the passage in the centre again made, &c., and the basket again placed on the fire. It is from time to time examined, and when the leaves have become so crisp that they break by the slightest pressure of the fingers, it is taken off, when the tea is ready. All the different kinds of leaves underwent the same operation. The tea is now little by little put into boxes, and first pressed down with the hands and then with the feet (clean stockings having been previously put on).

There is a small room inside of the tea-house, 7 cubits square and 5 high, having bamboos laid across on the top to support a network of bamboo and the sides of the room smeared with mud to exclude the air. When there is wet weather, and the leaves cannot be dried in the sun, they are laid out on the top of this room, on the network, on an iron pan, the same as is used to heat the leaves; some fire is put into it, either of grass or bamboo, so that the flame may ascend high; the pan is put on a square wooden frame, that has wooden rollers on its legs, and pushed round and round this little room by one man, while another feeds the fire, the leaves on the top being occasionally turned; when they are a little withered, the fire is taken away, and the leaves brought down and manufactured into tea, in the same manner as if it had been dried in the sun. But this is not a good plan, and never had recourse to if it can be possibly avoided.

Preparation of factitious Green Tea. Tea is brought to Canton unprepared; as Bohea, *Soshung*, and is thrown into a hemispherical iron pan, kept very hot over a fire. The leaves are constantly stirred till they are thoroughly heated, when they are dyed, by adding, for each pound of tea, 1 spoonful of gypsum, 1 of turmeric, and 2 or 3 of Prussian blue. The leaves instantly change into a bluish-green, and after being well stirred for a few minutes, are taken out, being shrivelled by the heat. They are now sifted; the small longish leaves fall through the first sieve, and form Young Hyson: the roundest granular ones fall through the last, and constitute Gunpowder, or Choo-cha.

The observations of Liebig afford a satisfactory explanation of the cause of the great partiality of the poor, not only for tea, but for tea of an expensive and superior kind. He says, 'We shall never certainly be able to discover how men were first led to the use of the hot infusion of the leaves of a certain shrub (tea), or of a decoction of certain roasted seeds (coffee). Some cause there must be which will explain how the practice has become a necessary of life to all nations. But it is still more remarkable, that the beneficial effects of both plants on the health must be ascribed to one and the same substance (*theine* or *caffeine*), the presence of which in two vegetables, belonging to natural families, the products of different quarters of the globe, could hardly have presented itself to the boldest imagination. Yet recent researches have shown, in such a manner as to exclude all doubt, that *theine and caffeine* are in all respects identical.' And he adds, 'That we may consider these vegetable compounds, so remarkable for their action on the brain, and the substance of the organs of motion, as elements of food for organs as yet unknown, which are destined to convert the blood into nervous substance, and thus recruit the energy of the moving and thinking faculties.' Such a discovery gives a great importance to tea and coffee, in a physiological and medical point of view. See THEINE. Consult Watts's 'Dictionary of Chemistry.'

Indian Teas.—The following remarks by the late Dr. Archibald Campbell on Indian teas are of interest:—

Dr. Campbell's observation led him to believe that little was known of the subject in this country, although it was 40 years since tea was first discovered in Assam, growing wild, and 30 years since it was found in the same state in Cachar. It was very satisfactory to be able to state that the Indian authorities had been roused to vigorous exertions in providing means of communication between the tea-producing districts and the seaboard, Merchants from Thibet, Cashmere, and Afghanistan had crossed the Himalayas into India, and were carrying off the teas from the factories in the north-west at highly remunerative prices, bespeaking all the crop of next year in Kumaon, and paying down half the cash in advance. Taking all circumstances into consideration, the tea prospects were brighter than the pioneers of the great Indian industry could hitherto boast of. The tea crop of India was in 1873 about 20,000,000 lbs., of which Darjeeling contributed 2,600,000, increasing at the rate of 15 per cent. per annum on the land actually under tea cultivation—*i.e.*, 14,000 acres. For the present year (1874) 21,000,000lbs., could be reckoned on, of which 3,000,000 would be from Darjeeling. There were other lands which, when cultivated, would increase the supply. Dr. Campbell dwelt upon the quantity of spurious and adulterated China teas imported into England, and the extent to which pure Indian teas were kept back from the public for the purpose of mixing to make them saleable.

Tea Imported in 1873 *with a duty of* 6*d. per lb.*

	lbs.	Value
From Germany	116,032	£9,184
„ Holland	997,480	69,949
„ France	5,117,428	372,670
„ Egypt	927,718	76,718
„ China	137,246,372	9,261,937
„ Japan	311,849	18,365
„ United States of America	345,563	24,377
„ British India:		
„ Bombay and Scinde	22,719	2,096
„ Madras	31,838	2,613
„ Bengal and Burmah	18,416,506	1,517,484
„ Other countries	231,764	17,202
Total	163,765,269	11,372,595

Tea Imported in 1874.

	lbs.	Value
From British India	18,440,494	£1,621,980
„ China (including Hongkong and Macao)	131,669,908	9,105,307
„ Other countries	11,492,918	845,745
Total { Imports	161,603,410	11,573,032
Total { Home consumption	137,422,563	

TEAK. The produce of the *Tectona grandis;* a native of the mountainous parts of the Malabar coast. The African teak is thought by some to belong to another genus (*Oldfieldia Africana*).

TEASLE or **FULLER'S THISTLE** (*Chardon à carder*, Fr.; *Weberdistel*, Ger.); the head of the thistle, (*Dipsacus fullonum*), is employed to raise the nap of cloth. See Woollen Manufacture.

TEEL OIL. See Oils.

TEETH. In a typical tooth, as developed in most mammals, the greater part is composed of a substance called *dentine*, the crown being covered with a hard *enamel*, whilst the remainder of the tooth is coated with a cortical substance known as *cement*. *Ivory* is very similar to dentine. (See Ivory.)

Dr. Robert Dundas Thomson published the analyses of teeth by Alexander Nasmyth, Esq. The following table has been constructed from those analyses:—

	Enamel		Ivory		Bone
	Human adult	Elephant	Human adult	Elephant	For comparison
Organic matter	6·160	6·80	26·81	45·65	35·93
Phosphate of lime	89·160	82·55	66·42	52·30	51·12
Fluoride of calcium	·260	1·65	0·62		0·63
Phosphate of magnesia	...	...	...	...	...
Carbonate of lime	4·010	7·65	5·63	1·35	9·77
Chloride of sodium	...	1·05	0·15	0·06	0·59
Chloride of potassium					

For a large series of analyses of teeth by Von Bibra, see Watts's 'Dictionary of Chemistry.'

Teeth Imported in 1873 *: Elephant, Sea-cow, Sea-horse.*

	cwts.	Value
From Germany	640	22,282
" Malta	1,118	40,394
" Egypt	4,628	151,737
" West Coast of Africa (foreign):		
" Portuguese Possessions	449	19,629
" Not particularly designated	2,465	103,859
" East Coast of Africa (native)	69	6,000
" British Possessions on the Gold Coast	78	2,598
" " in South Africa	1,117	41,160
" Aden	277	13,440
" British India	1,201	58,082
" Other countries	1,343	47,448
Total	13,385	506,629

TELEGRAPHS. See Electro-Telegraphy.

TELLURIC BISMUTH. A telluride of bismuth. See Tetradymite.

TELLURIUM. One of the elementary bodies, usually classed amongst the metals, but it presents so great an analogy to sulphur and selenium, that many are disposed to remove it from the metallic bodies.

Tellurium was originally found in Transylvanian gold ores; and more recently it has been found with bismuth. Tellurium has a silvery lustre; its texture is crystalline and brittle. Its specific gravity is 6·65, and its atomic weight 64·5. From its extreme rarity, and consequent cost, it has not yet found any application in the arts.

TEMPERING OF STEEL. In metallurgy the process by which a certain required character is given to steel or any other metal.

The process of hardening or tempering steel is performed with due relation to the quality of the steel and the purposes for which it is designed. In most instances the hardening is effected in water and brine: saw-blades are thus hardened, after being heated in melted lead; and sabres are heated in a choked fire of charcoal, and then swung rapidly through the air. Mint-stamps are hardened in oil. The common method of procedure in hardening is this: The steel is overheated, cooled in cold water, and then annealed or tempered, by being so far re-heated that oil and tallow will burn on its surface; or the surface is ground and polished, and the steel re-heated until it assumes a certain colour. The gradations of colour consecutively follow: a light straw-yellow, violet, blue, and finally grey or black, when the steel again becomes as soft as though it had never been hardened.

TEMPLET. A gauge formed from a thin piece of metal, as a guide to the form of the work to be executed.

TENT. A portable lodge, consisting of canvas sustained by poles and stretched by cords, used for sheltering men, especially soldiers in camp, from the weather. Tents were commonly used in the earliest periods of man's history. The patriarchal tribes dwelt in tents. Layard describes one of the sculptured stones at Mosul as representing Sennacherib seated on a throne, placed at the entrance of a city. Behind the king was the royal tent supported by ropes, and an inscription, signifying 'This is the *tent* of Sennacherib, King of Assyria.' This was 700 years before Christ. We learn that Paul was a tent-maker, therefore in those days it was an important calling.

We have no space to enter into the history of tents or describe the varieties which have been used from time to time. A few words on modern tents must suffice:—

The hospital marquee is 29 feet long and 14½ feet wide and 15 feet high. This is supposed to accommodate not less than eighteen or more than twenty-four men. The height of each tent-pole is 13 feet 8 inches; the length of the ridge-pole 13 feet 10 inches; the height of the tent-walls from the ground 5 feet 4 inches. The weight of all the material of such a tent is stated by Major Rhodes to be 652 lbs.

The ventilation of tents has been admirably effected by Mr. Doyle, to whom we are indebted for the information contained in the following notes on the subject.

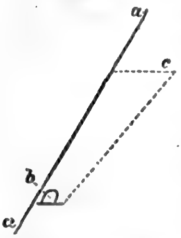
The old method of ventilating military tents was very defective. Ventilating openings were made at the top of the tent, but no means were provided for the admission of fresh air. The result was most unsatisfactory, as may be gathered from the following evidence given before the Sebastopol Committee:—

'The tents were very close indeed at night. When the tent was closed in wet weather, it was often past bearing. The men became faint from heat and closeness.'[1]

The problem then was to let in fresh air, and produce a draft without inconveniencing the soldiers as they slept.

The question attracted Mr. Doyle's notice during the period of the camp at Chobham, and it appearing to him to be one of very great importance, he undertook, with the sanction of Lord Raglan, then Master-General of the Ordnance, to try the following experiment:—

1947



He caused two openings to be made in the wall of a tent, about 4 feet from the ground, and introduced the air between the wall and a piece of lining somewhat resembling a carriage-pocket, thus: *a a*, the wall of the tent; *b*, the opening to admit air; *c*, the lining.

It will be seen that air so introduced would naturally take an upward direction, and that this communicating with the openings at the top of the tent, would probably produce the desired effect.

The following extract from the report on this experiment will show the actual result:—

'The ventilators (Mr. Doyle's) were found of great use in clearing the tent of the fetid atmosphere consequent upon a number of men sleeping in so confined a space. The men state that the heavy smell experienced before the tent was altered is almost banished.'

In subsequent experiments the number of the new openings was increased from two to three, and a greater amount of ventilation thus obtained. The result according to an official letter of thanks received on the subject, was 'quite successful.' The improvement has been since adopted into the service, and by these very simple means one of the most fruitful causes of sickness among our soldiers in camp finally removed.

TENT, a wine, so called from the Spanish *tinto*, 'deep-coloured,' it being of a deep red colour. It comes chiefly from Galicia, or Malaga. See WINE.

TERMINALIA CHEBULA. The name of a tree common in India, which produces Myrobalans. See Crookes's 'Handbook of Dyeing.'

TERNE-PLATE. Iron-plate coated with a mixture of tin and lead, instead of pure tin.

TERRA COTTA. This term means literally *baked earth*. It is known in the arts as the material of the ancient vases, amphoræ, pateræ, lamps, statues, and bassi-rilievi. Monumental vases of terra cotta have been found in the tombs, after the lapse of 2,000 years, in a fine state of preservation. The ancient terra-cotta vases are generally painted black, on a red or buff ground; but on some there are blue, yellow, and other colours. The style of ornamentation is much alike in all: a few narrow lines, or fillets, with dots, meander fretwork, laurel, ivy-leaf, and honeysuckle borders, adorning the rim, neck, and stand of the vases, the centre or body being covered with allegorical representations of gods, men, and animals. Terra cottas of the type of the early Greek, commonly called Etruscan vases, are found throughout the ancient Egyptian cities. The art of making the Greek terra cotta seems to have become extinct, about 150 years before Christ. The modes in which the Greek works were made have been subjects of much controversy among the learned in art. The body, or substance, appears to a potter, in a commercial point of view, of the lowest grade, as it is common clay, very porous, and coarse-grained. By some authors it is said they were made of clay, mixed with sand only, and by others, with clay mixed with cement. The most probable conclusion is, that some were made of clay only, some of clay and sand, and others (such as those of ground and monumental character, where it was important that the parts should be kept very true in firing), of clay mixed with potsherds and puzzolano or other detritus of lava. The works are less baked than modern pottery, and it is doubtful if it would stand exposure to the variations of such a climate as England. Among the remains of Greek pottery are gigantic amphoræ of very coarse grain, measuring as much as 8 feet in length by 3 feet in diameter, and of corresponding thickness. It is said that one of these great vessels was the tub of Diogenes. Vauquelin gives the following analysis of the Greek terra-cotta vases: silica, 53; alumina, 15; lime 8; oxide of iron, &c., 24.

The Roman terra cottas are of an entirely different character from those just described, and consist chiefly of cinerary urns, lamps, and pateræ; and these appear to have been moulded; the ornament is either incised or embossed, and odd fantastic shapes prevail.

Terra-cotta works of an architectural character are constantly met with in the buildings erected in Italy between the 12th and 17th centuries. The clay sketches and models of Michael Angelo, and other great sculptors, were rendered in terra cottas. Bramante employed terra cotta in decoration.

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[1] Evidence of Sergeant Dawson, Grenadier Guards.

The merit of reviving in England the manufacture of terra cotta belongs to Josiah Wedgwood, who in 1770 established large works in Staffordshire. About 1790 a pottery was established at Lambeth for the manufacture of decorative works; and terra cotta was made for many years by a lady of the name of Coade, and afterwards by Coade and Sealey. The chief materials used by them were the Dorset and Devonshire clays, with fine sand, flint, and potsherds. The chief portion of the old coats-of-arms above the shop-fronts of London were made of this terra cotta. About fifty years ago, Mr. Bubb, the sculptor, had a manufactory for terra cotta. The frieze of the Opera in the Haymarket is an example of his work.

To explain the mode of executing any work in terra cotta, it is best to describe the proper meaning of the words 'modelling,' 'moulding,' and 'casting.'

A model is an original work made by the sculptor in clay, and worked out by the fingers and small tools made of bone and steel, varying from about 6 to 10 inches in length. This original work of the artist is allowed to dry, and then the moulding operation commences. This process is effected by mixing plaster-of-Paris with water to the consistency of thick cream; this is spread over the model, and when it has set it is removed in sections, which, when again carefully united, form the mould, in which either clay or metal can be cast, and receive the form of the original work. For terra-cotta work, unless many copies of the original are wanted, moulds are not employed. When only one or two copies of a work are required, the original models are built up in a cellular manner, they are then dried and removed to a kiln and baked, being a perfectly original work.

When moulding is performed for terra-cotta works, sheets of clay are beaten on a bench to the consistency of glazier's putty, and pressed by the hand into the mould; according to the magnitude of the work and the weight it may have to sustain, the thickness of the clay is determined and arranged, and here consists a part of the art it would be impossible to describe, and which requires years of experience in such works to produce great works and fire them with certainty of success.

At the Crystal Palace, Sydenham, are several large works manufactured by Mr. J. M. Blashfield, who has extensive terra-cotta works at Stamford. The figure of 'Australia,' modelled by John Bell, nine feet in height, and burnt in one piece; the colossal Tritons modelled by the same artist, and other works, are examples. After the moulded article has become sufficiently dry, it is conveyed to a kiln. A slow fire is first made, and quickened until the heat is sufficient to blend and partially vitrify the material of which the mass is composed; when sufficiently baked, the kiln is allowed to cool, and the terra cotta is withdrawn.

A very fine red terra cotta, resembling that imported from Copenhagen and Belgium, has within the last few years been manufactured at Watcombe, near Torquay, in Devonshire.

TERRA DI SIENNA is a brown ferruginous ochre, employed in painting, obtained from Italy. It is a hydrous sesquioxide of iron, containing traces of arsenic; from which we may infer it is derived mainly from decomposition of arsenical pyrites. It is calcined before being used as a pigment, and is then known as *burnt* sienna. *Raw* sienna is not much employed; it contains water, which the calcined does not.

TERRA JAPONICA. See ACACIA; CATECHU; GAMBIER.

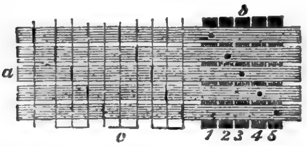
TESSERÆ. See TILES and ENCAUSTIC TILES.

TESTS are chemical reagents of any kind, which indicate, by special characters, the composition of the body to which they are applied. Analytical chemistry is based on the application of tests. See Watts's 'Dictionary of Chemistry.'

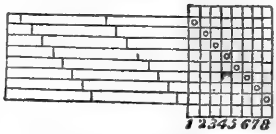
TETRADYMITE, or *Telluric Bismuth.* A telluride of bismuth, frequently containing sulphur. It is a common associate of gold.

TEXTILE FABRICS. The first business of the weaver is to adapt those parts of his loom which move the warp to the formation of the various kinds of ornamental figures which the cloth is intended to exhibit. This subject is called the *draught*, drawing or reading in, and the cording of looms. In every species of weaving, whether direct or cross, the whole difference of pattern or effect is produced, either by the succession in which the threads of warp are introduced into the heddles, or by the succession in which those heddles are moved in the working. The heddles being stretched between two shafts of wood, all the heddles connected by the same shafts, are called a leaf; and as the operation of introducing the warp into any number of leaves is called drawing a warp, the plan of succession is called the 'draught.' When this operation has been performed correctly, the next part of the weaver's business is to connect the different leaves with the levers or treddles by which they are to be moved, so that one or more may be raised or sunk by every treddle successively, as may be required to produce the peculiar pattern. These connections being made by coupling the different parts of the apparatus by cords, this operation is called the 'cording.' In order to direct the operator in this part of his business, especially if previously unacquainted with the particular pattern upon which he is employed, plans are drawn upon paper, specimens of which will be found in *figs.* 1948, 1949, &c. These plans are horizontal sections of a loom, the heddles being represented across the paper at *a*, and the treddles under them, and crossing them at right angles at *b*. In *figs.* 1948 and 1949 they are represented as if they were distinct pieces of wood, those across being the under shaft of each leaf of heddles, and those at the left hand the treddles. See Weaving. In actual weaving, the treddles are placed at right angles to the heddles, the sinking cords descending perpendicularly as nearly as possible to the centre of the latter. Placing them at the left hand, therefore, is only for ready inspection, and for practical convenience. At *c* a few threads of warp are shown as they pass through the heedles, and the thick lines denote the leaf with which each thread is connected. Thus, in *fig.* 1948, the right-hand thread, next to *a*, passes through the eye of a heddle upon the back leaf, and is disconnected with all the other leaves; the next thread passes through a heddle on the second leaf; the third, through the third leaf; the fourth, through the fourth leaf; and the fifth, through the fifth or front leaf. One set of the draught being now completed, the weaver recommences with the back leaf, and proceeds in the same succession again to the front. Two sets of the draught are represented in this figure, and the same succession, it is understood by weavers (who seldom draw more than one set), must be repeated until all the warp is included. When they proceed to apply the cords, the right-hand part of the plan at *b*, serves as a guide. In all the plans shown by these figures, excepting one which shall be noticed, a connection must be formed, by cording, between every leaf of heddles and every treddle: for all the leaves must either rise or sink. The raising motion is effected by coupling the leaf to one end of its correspondent top lever; the other end of this lever is tied to the long march below, and this to the treddle. The sinking connection is carried directly from under the leaf to the treddle. To direct a weaver which of these connections is to be formed with each treddle, a black spot is placed when a leaf is to be raised, where the leaf and treddle intersect each other upon the plan, and the sinking connections are left blank. For example, to cord the treddle 1, to the back leaf, put a raising cord, and to each of the other four, sinking cords; for the treddle 2, raise the second leaf, and sink the remaining four, and so of the rest; the spot always denoting the leaf or leaves to be raised. The *figs.* 1948 and 1949 are drawn for the purpose of rendering the general principle of this kind of plans familiar to those who have not been previously acquainted with them; but those who have been accustomed to manufacture and weave ornamented cloths, never consume time by representing either heddles or treddles as solid or distinct bodies. They content themselves with ruling a number of lines across a piece of paper, sufficient to make the intervals between these lines represent the number of leaves required. Upon these intervals, they merely mark the succession of the draught, without producing every line to resemble a thread of warp. At the left hand, they draw as many lines across the former as will afford an interval for each treddle: and in the squares produced by the intersections of these lines, they place the dots, spots, or ciphers which denote the raising cords. It is also common to continue the cross lines which denote the treddle a considerable length beyond the intersections, and to mark by dots, placed diagonally in the intervals, the order or succession in which the treddles are to be pressed down in weaving. The former of these modes has been adopted in the remaining *figs.* to 1957; but to save room, the latter has been avoided, and the succession marked by the order of the figures under the intervals which denote the treddles.

1948



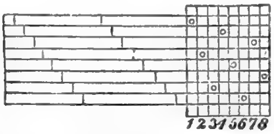
1949



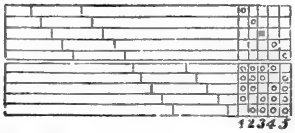
Some explanation of the various kinds of fanciful cloths represented by these plans may serve further to illustrate this subject, which is, perhaps, the most important of any connected with the manufacture of cloth, and will also enable a person who thoroughly studies them, readily to acquire a competent knowledge of the other varieties in weaving, which are boundless. *Figs.* 1948 and 1949 represent the draught and cording of the two varieties of tweeled cloth wrought with five leaves of heddles.

The first is the regular or run tweel, which, as every leaf rises in regular succession, while the rest are sunk, interweaves the warp and woof only at every fifth interval, and as the succession is uniform, the cloth, when woven, presents the appearance of parallel diagonal lines, at an angle of about 45° over the whole surface. A tweel may have the regularity of its diagonal lines broken by applying the cording as in *fig.* 1949. It will be observed, that in both figures the draught of the warp is precisely the same, and that the whole difference of the two plans consists in the order of placing the spots denoting the raising cords, the first being regular and successive, and the second alternate.

1950

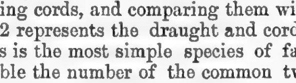


1951

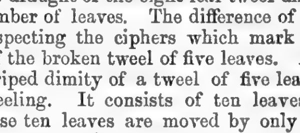


Figs. 1950 and 1951 are the regular and broken tweels which may be produced with eight leaves. This properly is the tweel denominated 'satin' in the silk manufacture, although many webs of silk wrought with only five leaves receive that appellation. Some of the finest Florentine silks are tweeled with sixteen leaves. When the broken tweel of eight leaves is used, the effect is much superior to what could be produced by a smaller number; for in this two leaves are passed in every interval, which gives a much nearer resemblance to plain cloth than the others. For this reason it is preferred in weaving the finest damasks. The draught of the eight-leaf tweel differs in nothing from the others, excepting in the number of leaves. The difference of the cording in the broken tweel will appear by inspecting the ciphers which mark the raising cords, and comparing them with those of the broken tweel of five leaves. *Fig.* 1952 represents the draught and cording of striped dimity of a tweel of five leaves. This is the most simple species of fanciful tweeling. It consists of ten leaves, or double the number of the common tweel. These ten leaves are moved by only five treddles, in the same manner as a common tweel. The stripe is formed by one set of the leaves flushing the warp, and the other set, the woof. The figure represents a stripe formed by ten threads, alternately drawn through each of the two sets of leaves. In this case, the stripe and the intervals will be equally broad, and what is the stripe upon one side of the cloth will be the interval upon the other, and *vice versâ.* But great variety of patterns may be introduced by drawing the warp in greater or small portions through either set. The tweel is of the regular kind, but may be broken by placing the cording as in *fig.* 1949. It will be observed that the cording-marks of the lower or front leaves are exactly the converse of the other set; for where a raising mark is placed upon one, it is marked for sinking in the other; that is to say, the mark is omitted; and all leaves which sink in the one, are marked for raising in the other; thus, one thread rises in succession in the back set, and four sink; but in the front set, four rise, and only one sinks. The woof, of course, passing over the four sunk threads, and under the raised one, in the first instance, is flushed above; but where the reverse takes place, as in the second it is flushed below; and thus the appearance of a stripe is formed. The analogy subsisting between striped dimity and dornock is so great, that before noticing the plan for fancy dimity, it may be proper to allude to the dornock, the plan of which is represented by *fig.* 1953.

1952



1953



The draught of dornock is precisely the same in every respect with that of striped dimity. It also consists of two sets of tweeling heddles, whether three, four, or five leaves are used for each set. The right-hand set of treddles is also corded exactly in the same way, as will appear by comparing them. But as the dimity is a continued stripe from the beginning to the end of the web, only five treddles are required to move ten leaves. The dornock being chequer-work, the weaver must possess the power of reversing this at pleasure. He therefore adds five more treddles, the cording of which is exactly the reverse of the former; that is to say, the back leaves, in the former case, having one leaf raised, and four sunk, have, by working with these additional treddles, one leaf sunk and four leaves raised. The front leaves are in the same manner reversed, and the mounting is complete. So long as the weaver continues to work with either set, a stripe will be formed, as in the dimity; but when he changes his feet from one set to the other, the whole effect is reversed, and the chequers formed. The dornock pattern upon the design-paper, *fig.* 1953, may be thus explained: let every square of the design represent five threads upon either set of the heddles, which are said by weavers to be once over the draught, supposing the tweel to be one of five leaves; draw three parallel lines, as under, to form two intervals, each representing one of the sets; the draught will then be as follows:—

1954

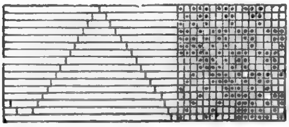
4		1		4		1		1		4		1	
	4		4		1		1		1		4		4

The above is exactly so much of the pattern as is there laid down, to show its appearance; but one whole range of the pattern is completed by the figure 1, nearest to the right hand upon the lower interval between the lines, and the remaining figures, nearer to the right, form the beginning of a second range or set. These are to be repeated in the same way across the whole warp. The lower interval represents the five front leaves; the upper interval, the five back ones. The first figure 4, denotes that five threads are to be successively drawn upon the back leaves, and this operation repeated four times. The first figure 4, in the lower interval, expresses that the same is to be done upon the front leaves; and each figure, by its diagonal position, shows how often, and in what succession, five threads are to be drawn upon the leaves which the interval in which it is placed represents.

Dornocks of more extensive patterns are sometimes woven with 3, 4, 5, and even 6 set of leaves; but after the leaves exceed 15 in number, they both occupy an inconvenient space, and are very unwieldy to work. For these reasons the diaper harness is in almost every instance preferred.

Fig. 1955 represents the draught and cording of a fanciful species of dimity, in which it will be observed that the warp is not drawn directly from the back to the front leaf, as in the former examples; but when it has arrived at either external leaf, the draught is reversed, and returns gradually to the other. The same draught is frequently used in the tweeling, when it is wished that the diagonal lines should appear upon the cloth in a zigzag direction. This plan exhibits the draught and cording which will produce the pattern upon the design-paper in *fig.* 1948. Were all the squares produced by the intersection of the lines denoting the leaves and treddles, where the raised dots are placed, filled the same as on the design, they would produce the effect of exactly one fourth of that pattern. This is caused by the reversing of the draught, which gives the other side reversed as on the design; and when all treddles, from 1 to 16, have been successively used in the working, one-half of the pattern will become complete. The weaver then goes again over his treddles, in the reversed order of the numbers, from 17 to 30, when the other half of the pattern will be completed. From this similarity of the cording to the design, it is easy, when a design is given, to make out the draught and cording proper to work it; and when the cording is given, to see its effect upon the design.

1955



1956

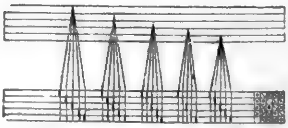
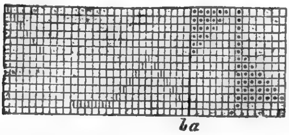


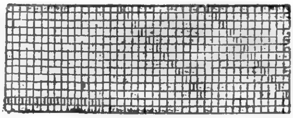
Fig. 1956 represents the draught of the diaper mounting, and the cording of the front leaves which are moved by treddles. From the plan, it will appear that five threads are included in every mail of the harness, and that these are drawn in single threads through the front leaves. The cording forms an exception to the general rules, that when one or more leaves are raised, all the rest must be sunk; for in this instance, one leaf rises, one sinks, and three remain stationary. An additional mark, therefore, is used in this plan. The dots, as formerly, denote raising cords; the blanks, sinking cords; and where the cord is to be totally omitted, the cross marks × are placed.

Fig. 1957 is the draught and cording of a spot whose two sides are similar, but reversed. That upon the plan forms a diamond, similar to the one drawn upon the design-paper in the diagram, but smaller in size. The draught here is reversed, as in the dimity plan, and the treading is also to be reversed, after arriving at 6, to complete the diamond. Like it, too, the raising marks form one-fourth of the pattern. In weaving spots, they are commonly placed at intervals, with a portion of plain cloth between them, and in alternate rows, the spots of one row being between those of the other. But as intervals of plain cloth must take place, both by the warp and woof, 2 leaves are added for that purpose. The front, or ground leaf, includes every second thread of the whole warp; the second, or plain leaf, that part which forms the intervals by the warp. The remaining leaves form the spots: the first six being allotted to one row of spots, and the second six to the next row, where each spot is in the centre between the former. The reversed draught of the first is shown entire, and is succeeded by 12 threads of plain. One-half of the draught of the next row is then given, which is to be completed exactly like the first, and succeeded by 12 threads more of plain; when, one set of the pattern being finished, the same succession is to be repeated over the whole warp. As spots are formed by inserting woof of coarser dimensions than that which forms the fabric, every second thread only is allotted for the spotting. Those included in the front, or ground leaf are represented by lines, and the spot-threads between them, by marks in the intervals, as in the other plans.

1957



1958

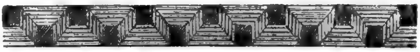


The treddles necessary to work this spot are, in number, 14. Of these the two in the centre, *a*, *b*, (*fig.* 1957) when pressed alternately, will produce plain cloth; for *b* raises the front leaf, which includes half the warp, and sinks all the rest; while *a* exactly reverses the operation. The spot-treddles on the right hand work the row contained in the first six spot-leaves: and those upon the left hand, the row contained in the second six. In working spots, one thread, or shot of spotting-woof, and two of plain, are successively inserted, by means of two separate shuttles.

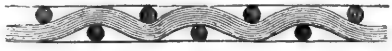
Dissimilar spots are those whose sides are quite different from each other. The draught only of these is represented by *fig.* 1958. The cording depends entirely upon the figure.

Fig. 1959 represents any solid body composed of parts *lashed* together. If the darkened squares be supposed to be beams of wood, connected by cordage, they will give a precise idea of textile fabric. The beams cannot come into actual contact, because, if the *lashing* cords were as fine even as human hairs, they must still require space. The thickness is that of one beam and one cord; but if the cords touch each other, it may then be one beam and two cords; but it is not possible in practical weaving to bring every thread of weft into actual contact. It may, therefore, be assumed, that the thickness is equal to the diameter of one thread of the warp, added to that of one yarn of the weft; and when these are equal, the thickness of the cloth is double of that diameter. Denser cloth would not be sufficiently pliant or flexible.

1959



1960



1961

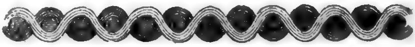
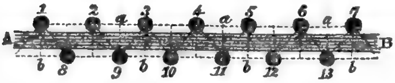


Fig. 1960 is a representation of a section of cloth of an open fabric, where the round dots which represent the warp are placed at a considerable distance from each other.

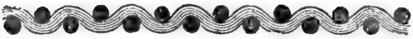
Fig. 1961 may be supposed a plain fabric of that description which approaches the most nearly to any idea we can form of the most dense or close contact of which yarn can be made susceptible. Here the warp is supposed to be so tightly stretched in the loom as to retain entirely the parallel state, without any curvature, and the whole flexure is therefore given to the woof. This mode of weaving can never really exist; but if the warp be sufficiently strong to bear any tight stretching, and the woof be spun very soft and flexible, something very near it may be produced. This way of making cloth is well fitted for those goods which require to give considerable warmth; but they are sometimes the means of very gross fraud and imposition; for if the warp is made of very slender threads, and the woof of slackly twisted cotton or woollen yarn, where the fibrils of the stuff, being but slightly brought into contact, are rough and oozy, a great appearance of thickness and strength may be given to the eye, when the cloth is absolutely so flimsy that it may be torn asunder as easily as a sheet of writing-paper. Many frauds of this kind are practised.

In *fig.* 1962 is given a representation of the position of a fabric of cloth in section, as it is in the loom before the warp has been closed upon the woof, which still appears as a straight line. This figure may usefully illustrate the direction and ratio of contraction which must unavoidably take place in every kind of cloth, according to the density of the texture, the dimensions of the threads, and the description of the cloth. Let A, B, represent one thread of woof completely stretched by the velocity of the shuttle in passing between the threads of warp which are represented by the round dots, 1, 2, &c., and those distinguished by 8, 9, &c. When these threads are closed by the operation of the needles to form the inner texture, the first tendency will be to move in the direction 1 *b*, 2 *b*, &c., for those above, and in that of 8 *a*, 9 *a*, &c., for those below; but the contraction for A, B, by its deviation from a straight to a curved line, in consequence of the compression of the warp-threads 1 *b*, 2 *b*, &c., and 1 *a*, 2 *a*, &c., in closing, will produce by the action of the two powers at right angles to each other, the oblique or diagonal direction denoted by the lines 1, 8—2, 9, to the left, for the threads above, and that expressed by the lines 2, 8—3, 9, &c., to the right, for the threads below. Now, as the whole deviation is produced by the flexure of the thread A, B, if A is supposed to be placed at the middle of the cloth, equidistant from the two extremities, or *selvages* as they are called by weavers, the thread at 1 may be supposed to move really in the direction 1 *b*, and all the others to approach to it in the directions represented, whilst those to the right would approach in the same ratio, but the line of approximation would be inverted. *Fig.* 1963 represents the common fabric used for lawns, muslins, and the middle kind of goods, the excellence of which neither consists in the greatest strength, nor in the greatest transparency. It is entirely a medium between *fig.* 1960 and *fig.* 1961.

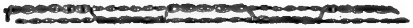
1962



1963



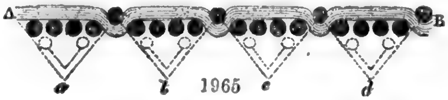
1964



In the efforts to give great strength and thickness to cloth, it will be obvious that the common mode of weaving, by constant intersection of warp or woof, although it may be perhaps the best which can be devised for the former, presents invincible obstructions to the latter beyond a certain limit. To remedy this, two modes of weaving are in common use, which, while they add to the power of compressing a great company of materials in a small compass, possess the additional advantage of affording much facility for adding ornament to the superficies of the fabric. The first of these is double cloth, or two webs woven together, and joined by the operation. This is chiefly used for carpets; and its geometrical principles are entirely the same as those of plain cloth, supposing the webs to be sowed together. A section of the cloth will be found in *fig.* 1964. See CARPETS.

Of the simplest kind of tweeled fabric, a section is given in *fig.* 1965.

The great and prominent advantage of the tweeled fabric in point of texture arises from the facility with which a very great quantity of materials may be put closely together. In the figure, the warp is represented by the dots in the same straight line as in the plain fabrics; but if we consider the direction and ratio of contraction, upon principles similar to those laid down in the explanation given of *fig.* 1962, we shall readily discover the very different way in which the tweeled fabric is affected.



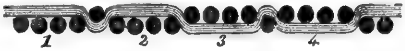
1965

When the dotted lines are drawn at *a*, *b*, *c*, *d*, their direction of contraction, instead of being upon every second or alternate thread, is only upon every fifth thread, and the natural tendency would consequently be, to bring the whole into the form represented by the lines and dotted circles at *a*, *b*, *c*, *d*. In point, then, of thickness, from the upper to the under superficies, it is evident that the whole fabric has increased in the ratio of nearly three to one. On the other hand, it will appear, that four threads or cylinders being thus put together in one solid mass, might be supposed only one thread, or like the strands of a rope before it is twisted; but, to remedy this, the thread being shifted every time, the whole forms a body in which much agggregate matter is compressed; but where, being less firmly united, the accession of strength acquired by the accumulation of materials is partially counteracted by the want of equal firmness of junction.

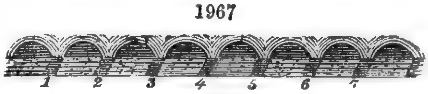
The second quality of the tweeled fabric, *susceptibility of receiving ornament*, arises from its capability of being inverted at pleasure, as in *fig.* 1966. In this figure, we have, as before, four threads, and one alternately intersected; but here the four threads marked 1 and 2 are under the woof, while those marked 3 and 4 are above.

Fig. 1967 represents that kind of tweeled work which produces an ornamental effect, and adds even to the strength of a fabric, in so far as accumulation of matter can be considered in that light. The figure represents a piece of velvet cut in section, and of that kind which, being woven upon a tweeled ground, is known by the name of Genoa velvet. 1st. Because, by combining a great quantity of material in a small compass, they afford great warmth. 2nd. From the great resistance which they oppose to external friction, they are very durable. And, 3rd. Because, from the very nature of the texture, they afford the finest means of rich ornamental decoration.

1966



1967



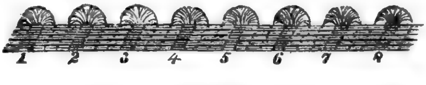
The use of velvet cloths in cold weather is a sufficient proof of the truth of the first. The manufacture of plush, corduroy, and other stuffs for the dress of those exposed to the accidents of laborious employment, evinces the second; and the ornamented velvets and Wilton carpeting are demonstrative of the third of these positions.

In the figure, the diagonal form which both the warp and woof of cloth assume, is very apparent from the smallness of the scale. Besides what this adds to the strength of the cloth, the flushed part, which appears interwoven, at the darkly-shaded intervals 1, 2, &c., forms, when finished, the whole covering or upper surface. The principle, in so far as regards texture, is entirely the same as any other tweeled fabric.

Fig. 1968, which represents corduroy, or king's cord, is merely striped velvet. The principle is the same, and the figure shows that the one is a copy of the other. The remaining figures represent those kinds of work which are of the most flimsy and open description of texture; those in which neither strength, warmth, nor durability are much required, and of which openness and transparency are the chief recommendations.

Fig. 1969 represents common gauze, or *linau*, a substance very much used for various purposes. The essential difference between this description of cloth and all others, consists in the warp being turned or twisted like a rope during the operation of weaving, and hence it bears a considerable analogy to *lace*. The twining of gauze is not continued in the same direction, but is alternately from right to left, and *vice versâ*, between every intersection of the woof. The fabric of gauze is always open, flimsy, and transparent; but from the turning of the warp, it possesses an uncommon degree of strength and tenacity in proportion to the quantity of material which it contains. This quality, together with the transparency of the fabric, renders it peculiarly adapted for ornamental purposes of various kinds, particularly for flowering or figuring, either in the loom or by the needle. In the warp of gauze there arises a much greater degree of contraction during the weaving than in any other species of cloth; and this is produced by the turning. The twisting between every intersection of weft amounts precisely to one complete revolution of both threads: hence this difference exists between this and every other species of weaving, namely, that the one thread of warp is always above the woof, and the contiguous thread is always below.

1968



1969

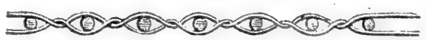
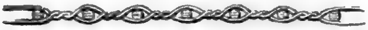


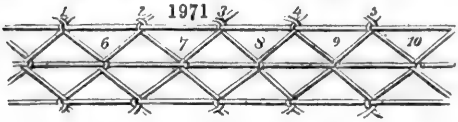
Fig. 1970 represents a section of another species of twisted cloth, which is known by the name of 'catgut,' and which differs from the gauze only, by being subjected to a greater degree of twine in weaving; for, in place of one revolution between each intersection, a revolution and a half are always given; and thus the warp is alternately above and below, as in other kinds of weaving.

Fig. 1971 is a superficial representation of the most simple kind of ornamental network produced in the loom. It is called a whip-net by weavers, who use the term 'whip' for any substance interwoven in cloth for ornamental purposes, when it is distinct from the ground of the fabric. In this the difference is merely in the crossing of the warp; for it is very evident that the crossings at 1, 2, 3, 4, and 5, are of different threads from those at 6, 7, 8, and 9.

1970



1971



1972

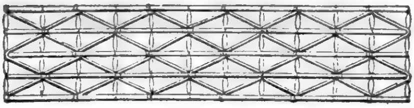
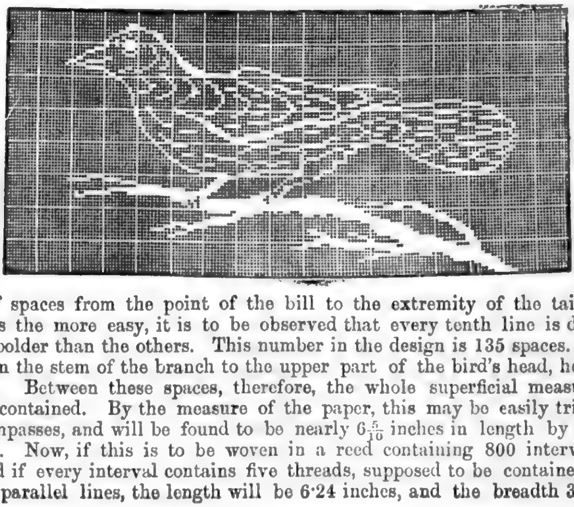


Fig. 1972 represents, superficially, what is called the 'mail-net,' and is merely a combination of common gauze and the whip-net in the same fabric. The gauze here being in the same direction as the dotted line in the former figure, the whole fabric is evidently a continued succession of right-angle triangles, of which the woof forms the basis, the gauze part the perpendiculars, and the whip parts the hypothenuses. The contraction here being very different, it is necessary that the gauze and whip parts should be stretched upon separate beams.

In order to design ornamental figures upon cloths, the lines which are drawn from the top to the bottom of the paper may be supposed to represent the warp; and those drawn across, the woof of the web; any number of threads being supposed to be included between every two lines. The paper thus forms a double scale, by which, in the first instance, the size and form of the pattern may be determined with great precision; and the whole subsequent operations of the weaver regulated, both in mounting and working his loom. To enable the projector of a new pattern to judge properly of its effects, when transferred from the paper to the cloth, it will be essentially necessary that he should bear constantly in his view the comparative scale of magnitude which the design will bear in each, regulating his ideas always by square or superficial measurement. Thus, in the large design, *fig.* 1973, representing a bird perched upon the branch of a tree, it will be proper, in the first place to count the number of spaces from the point of the bill to the extremity of the tail; and to render this the more easy, it is to be observed that every tenth line is drawn considerably bolder than the others. This number in the design is 135 spaces. Counting again, from the stem of the branch to the upper part of the bird's head, he will find 76 spaces. Between these spaces, therefore, the whole superficial measure of the pattern is contained. By the measure of the paper, this may be easily tried with a pair of compasses, and will be found to be nearly $6\frac{5}{10}$ inches in length by $3\frac{3}{16}$ inches in breadth. Now, if this is to be woven in a reed containing 800 intervals in 37 inches, and if every interval contains five threads, supposed to be contained between every two parallel lines, the length will be 6·24 inches, and the breadth 3·52 inches

1973



nearly; so that the figure upon the cloth would be very nearly of the same dimensions as that upon the paper; but if a 1,200 reed were used, instead of an 800, the dimension would be proportionally contracted.

A correct idea being formed of the design, the weaver may proceed to mount his loom according to the pattern; and this is done by two persons, one of whom takes from the design instructions necessary for the other to follow in tying his cords.

1974

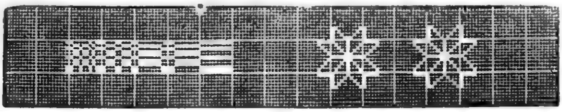
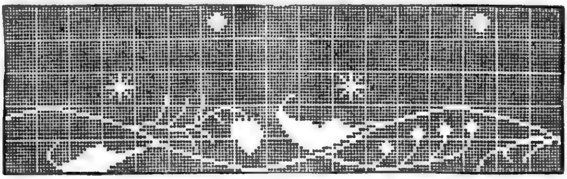


Fig. 1974 is a representation of the most simple species of table linen, which is merely an imitation of chequer-work of various sizes; and is known in Scotland, where the manufacture is chiefly practised, by the name of 'dornock.' When a pattern is formed upon tweeled cloth, by reversing the flushing, the two sides of the fabric being dissimilar, one may be supposed to be represented by the black marks, and the other by the part of the figure which is left uncoloured. For such a pattern as this, two sets of common tweeled-heddles, moved in the ordinary way, by a double succession of heddles, are sufficient. The other part of *fig.* 1974 is a design of that intermediate kind of ornamental work which is called diaper, and which partakes partly of the nature of the dornock, and partly of that of the damask and tapestry.

1975



The principle upon which all these descriptions of goods are woven is entirely the same, and the only difference is in the extent of the design, and the means by which it is executed. *Fig.* 1975 is a design for a border of a handkerchief or napkin, which may be executed either in the manner of damask, or as the spotting is practised in the lighter fabrics.

TEXTILE FIBRES CONDENSED. Mr. John Mercer's plan of transforming cotton and flax into fibres of fine silky texture, while their strength and substance are increased, excited much interest a few years since. He subjected them to the action of caustic alkaline lye, sulphuric acid, or to solution of chloride of zinc, of such strength and at such a temperature as produced certain remarkable changes in them, quite the reverse of what most people would have expected. The mode of operating according to this invention, upon cloth made wholly or partially of any vegetable-fibres and bleached, is as follows:—The cloth is passed through a padding machine charged with caustic soda or caustic potash at 60° or 70° of Twaddle's hydrometer, at the common temperature of the atmosphere (say 60° Fahr. or under); then, without being dried, it is washed in water; and, after this, it is passed through dilute sulphuric acid, and washed again. Or the cloth is conducted over and under a series of rollers in a cistern containing caustic soda or caustic potash at 40° to 50° Twaddle, at the ordinary temperature (the last two rollers being set so as to squeeze the excess of soda or potash back into the cistern); and then it is passed over and under rollers placed in a series of cisterns, which are charged at the commencement of the operation with water only; so that when the cloth arrives at the last cistern, nearly all the alkali has been washed out of it. After the cloth has either gone through the padding machine or through the cisterns, it is washed in water, passed through dilute sulphuric acid, and again washed in water.

When grey or unbleached cloth, made from the above-mentioned fibrous material, is to be treated, it is first boiled or steeped in water, so as to wet it thoroughly; then most of the water is removed by the squeezer or hydro-extractor; and, after this, it is passed through the soda- or potash-solution, &c., as before described.

Warps, either bleached or unbleached, are treated in the same manner; but, after passing through the cistern containing the alkali, they are passed through squeezers or through a hole in a metal plate, to remove the alkali; and then the warps are conducted through the water cisterns, 'soured,' and washed, as before described.

When thread or hank yarn is to be operated upon, the threads or yarns are immersed in the alkali and then wrung out (as is usually done in sizing or dyeing them); and afterwards they are subjected to the above-mentioned operations of washing, souring, and washing in water.

When any fibre in the raw state, or before it is manufactured, is to be treated, it is first boiled in water, and then freed from most of the water by the hydro-extractor or a press; after which it is immersed in the alkaline solution, and the excess of alkali is removed by the hydro-extractor or a press; then it is washed in water, soured with dilute sulphuric acid, and washed again; and, finally, the water is removed by the hydro-extractor or a press.

The following are the effects produced by the above operations upon cloth made of vegetable fibrous material, either alone or mixed with animal fibrous material:—The cloth will have shrunk in length and breadth, or have become less in its external dimensions, but thicker and closer; so that by the chemical action of caustic soda or caustic potash on cotton and other vegetable fabrics, an effect will be produced somewhat analogous to that which is produced on woollen by the process of fulling or milling; the cloth will likewise have acquired greater strength and firmness—greater force being required to break each fibre—it will be found to have become heavier than it was previously to being acted upon by the alkali, if in both cases it be weighed at the temperature of 60° Fahr., or under. It will also have acquired greatly augmented and improved powers of receiving colours in printing and dyeing.

THALLIUM. (*Symb.* Tl; *at. wt.* 204.) The existence of a new elementary substance in the deposit formed in the leaden chambers of a sulphuric-acid factory was indicated by Mr. W. Crookes as far back as March 30, 1861. Mr. Crookes announced his discovery in the following terms:—

'In the year 1850, upwards of 10 lbs. of the seleniferous deposit from the sulphuric acid manufactory at Tilkerode, in the Hartz Mountains, were placed at my disposal, for the purpose of extracting from it the selenium, which was afterwards employed in an investigation upon the selenocyanides. Some residues which were left in the purification of the crude selenium, and which from their reactions appeared to contain tellurium, were collected together and placed aside for examination at a more convenient opportunity. They remained unnoticed until the beginning of 1862, when, requiring some tellurium for experimental purposes, I attempted its extraction from these residues. Knowing that the spectra of the incandescent vapours of both selenium and tellurium were free from any strongly-marked line which might lead to the identification of either of these elements, it was not until I had in vain tried numerous chemical methods for isolating the tellurium which I supposed to be present, that the method of spectrum analysis was used. A portion of the residue, introduced into a blue gas-flame, gave abundant evidence of selenium; but as the alternate light and dark bands due to this element became fainter, and I was expecting the appearance of the somewhat similar but closer bands of tellurium, suddenly a *bright green line* flashed into view and as quickly disappeared. An isolated green line in this portion of the spectrum was new to me. I had become intimately acquainted with the appearance of most of the artificial spectra during many years' investigation, and had never before met with a similar line to this; and as from the chemical processes through which this residue had passed the elements which could possibly be present were limited to a few, it became of interest to discover which of them occasioned this green line. After numerous experiments, I have been led to the conclusion that it is caused by the presence of a new element, belonging to the sulphur group; but unfortunately the quantity of material upon which I have been able to experiment has been so small, that I hesitate to assert this very positively.'

Thallium is a soft heavy metal, resembling lead; it melts at 294° C., and is completely volatile below a red heat, both in the elementary state and in combination (except when united with a heavy fixed metal). From its hydrochloric solution it is readily precipitated by metallic zinc in the form of a heavy black powder insoluble in the acid liquid. Ammonia added very gradually, until in slight excess, to its acid solution gives no precipitate or colouration whatever, neither does the addition of carbonate or oxalate of ammonia to its alkaline solution. Dry chlorine passed over it at a dull red heat unites with it, forming a readily volatile chloride soluble in water. Sulphuretted hydrogen passed through its hydrochloric solution precipitates it incompletely, unless only a trace of free acid is present; but in an alkaline solution an immediate precipitation of a heavy black powder takes place. Fused with carbonate of soda and nitre, it becomes soluble in water.

Mr. Crookes afterwards found the new element in two or three specimens of native sulphur, and especially in some specimens from the Liparian Islands. Some samples of Spanish pyrites were likewise found to contain traces of the substance. Mr. Crookes called the new element *Thallium* (from Gr. *θαλλός*, *thallos*, 'budding twig'); and described a process by which it may be separated. Thallium is also found in some lithia-micas (*lepidolite*), and in the Swedish mineral called *Crookesite*, a selenide of copper and thallium, which contains as much as 19 per cent. of thallium.

On May 16, 1862, M. Lamy made known the result of his researches and experiments on a deposit formed, after the chambers had been fed for a considerable time with sulphurous acid generated by the combustion of Belgian pyrites from the mines of St. Oneux near Spa. M. Frederick Kuhlmann, jun. had extracted several specimens of selenium, one of which he placed at the disposal of M. Lamy. On submitting this specimen to spectrum analysis, M. Lamy observed (early in 1862) the same green line which had been the starting-point of Mr. Crookes' researches. It thus appears that M. Lamy was led by independent observations of his own to the detection of the green line-producing body previously observed by Mr. Crookes. M. Lamy, however, being fortunate enough to have a very considerable amount of the thalliferous deposit at his disposal, was enabled to pursue his investigation on a proportionately extensive scale. He began a series of experiments with the view of isolating the element, and soon succeeded in separating very appreciable quantities of the new body, in the form of a metallic ingot.

For the preparation of the salts of thallium, see Watts's 'Dictionary of Chemistry.'

THEBAINE. One of the numerous alkaloïds obtained from opium.

THEINE. Syn. *Caffeine.* $C^{16}H^{10}N^{4}O^{4}$ ($\mathbf{C^{8}H^{10}N^{4}O^{2}}$). A feeble base contained in tea, coffee, and, in fact, in most of the plants used in the manner of tea; such as Paraguay and Guarana tea. See CAFFEINE and TEA.

THÉNARD'S BLUE, or *Cobalt Blue*, is prepared by digesting the oxide of cobalt with nitric acid, evaporating the nitrate of cobalt formed, almost to dryness; diluting it with water, and filtering, to separate some arsenate of iron, which usually precipitates. The clear liquor is to be poured into a solution of phosphate of soda, when an insoluble phosphate of cobalt falls. This being well washed, is to be intimately mixed in its soft state with eight times its weight of well-washed gelatinous alumina, which has been obtained by pouring a solution of alum into water of ammonia in excess. The uniformly-coloured paste is to be spread upon plates, dried in a stove, then bruised dry in a mortar, enclosed in a crucible, and subjected to a cherry-red heat for half an hour. On taking out the crucible, and letting it cool, the fine blue pigment is to be removed into a bottle, which is to be stoppered till used.

The arsenate of cobalt may be substituted, in the above process, for the phosphate, but it must be mixed with sixteen times its weight of the washed gelatinous alumina. The arsenate is procured by pouring the dilute nitrate of cobalt into a solution of arsenate of potash. If nitrate of cobalt be mixed with alumina, and the mixture be treated as above described, a blue pigment will also be obtained, but paler than the preceding, showing that the colour consists essentially of alumina stained with oxide of cobalt. See COBALT BLUE.

THEOBROMA CACAO. The Cocoa or Cacao tree: from the seeds of which both chocolate and cocoa are prepared. See COCOA.

THEOBROMINE is a chemical principle found in cocoa-beans. It is extracted by boiling with water, filtering, precipitating with acetate of lead, separating the precipitate after washing it, and then decomposing it by sulphuretted hydrogen.

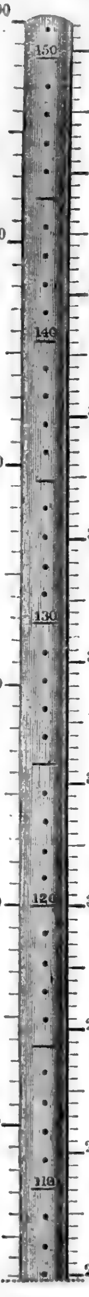
THEOLINE. See ABIETENE.

THERMOGRAPHY. A term proposed by the Editor of this Dictionary, in December 1842, to express the 'Art of Copying Engravings, &c. on Metal Plates;' the effect being due in all cases to the influence of heat-radiations. The process is fully described in 'Researches on Light,' by Mr. Robert Hunt.

THERMOMETER. An instrument used, as its name signifies, as a measure of heat. A description of this valuable instrument belongs to Physics. The principle upon which it is constructed depends upon the expansion of some fluid or solid by heat. We may adopt any body as our heat-measurer, if the rate of expansion is uniform for equal increments of heat, and we determine by previous experiments the rate of expansion to which it is subject, and construct a fixed scale. Usually either mercury or spirits of wine is employed.

Thermometrical Table, by Dr. Alfred S. Taylor, F.R.S.—The accompanying thermometrical table by Dr. A. Taylor has been copied from a thermometer in his possession, graduated on the scales of Fahrenheit, Réaumur, and Celsius, or the Centigrade. It has been designed to obviate the necessity for those perplexing calculations, so often rendered necessary by the use of different methods of graduation in England and on the Continent. In most chemical works, we find, besides the rules given for the conver-

CENTIGRADE. RÉAUMUR. FAHRENHEIT.



Chlor. Cyanogen vol. 190

Tin and lead, p. æ. m.; also Alloy 18 T. 4 L.
(Plumbers' solder).
Sat. sol. Chloride zinc boils.

Alloy 4 T. 1 L. m.

Oxalic ether, b. 1·09.
Sulphuric acid, 1·67 boils.
pr. steam, 10 at.

Paranaphthaline, m., alloy 12 T. 4 L. melts. 180
Oil of oranges, b. 0·835.
Starch converted to dextrine.

pr. steam, 9 at.
Elast. Turp. v. 53·8. Sulphuric acid, 1·65 boils.
Alloy 10 T. 4 L. m.

Alloy 9 T. 4 L. m.
pr. steam, 8 at.
Alloy 8 T. 4 L. m.
Alloy 7 T. 4 L. m. 170
pr. steam, 7·5 at.
Alloy 1 B. 2 T. m.

pr. steam, 7 at.

Alloy 8 B. 28 L. 24 T. m.
Oil elemi, b. 0·852.

pr. steam, 6·5 at.

Elast. A. V. 137·28.
pr. steam, 6 at. Fusible alloy, 8 B. 32 L. 36 T. m. 160
Alloy 8 B. 32 L. 34 T. m.
Elast. A. V. 131·57.
Fulminating silver explodes.
pr. steam, 5·5 at.

Elast. A. V. 125·85.
Elast. Turp. v. 33·5.
pr. steam, 5 at.
Elast. A. V. 120·03.

Elast. Turp. v. 30. Sat. nit. lime boils.
Sulphur burns feebly.
Elast. A. V. 114·15. 150
Terbromide Silicon, b.
4 pts. sulphuric acid, and 1 pt. water mixed; pr. steam, 4·5 at.
Mastich resin, m.
Alloy 8 B. 16 L. 18 T. m.
Elast. A. V. 108·31; Temp. of certain factories.
Nicotine distils.
pr. steam, 4 at.

Elast. A. V. 102·45.
Fulminating gold explodes.
Alloy 8 B. 16 L. 14 T. m.

pr. steam, 3·5 at.
Chlor. cyanogen, m.; S. G. 1·32. 140
Grape-sugar to Caramel.
Elast. A. V. 90·99.

Sat. nit. ammonia boils.

pr. steam, 3 at.
Pimelic acid, m.; Elast. A. V. 79·94.

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pr. steam, 12 at.
372 Zinc pulverisable.
Arsenious acid vol.; Salicylous acid b.
Phenic or carbolic acid boils.

Bichlor. carbon, b. d. v. 4·7.
pr. steam, 11 at.
Fulminating mercury explodes.

Alloy 15 T. 4 L. m.

362 Alloy 14 T. 4 L. m.
Elast. Turp. V. 60·8.
Alloy 13 T. 4 L. m. Aniline boils.

Paranaphthalin or anthracene m.
Arsenic vol.; sugar melts; hydruret of benzole m.
Succinic acid melts.
Gun-cotton explodes.
Alloy 8 B. 32 L. 24 T. m.; Citrilene b. 0·88.*

352 Alloys 5 T. 4 L., and 11 T. 4 L. m.
Sulphuret solid; iodine boils, d. v. 8·69.
Malic acid m.
Alloy 8 B. 32 L. 26 T. m.

Oil of lemons boils, 0·848.
Oil of Cascarilla b. 0·938. Sulphide Nitrogen explodes.

342 Caoutchoucine boils.
Elast. Turp. V. 47·3.

Kakodyl b.
Sat. acet. potash boils; eupion b.

Alloy 6 T. 4 L. m.

332 Alloy 8 B. 32 L. 28 T. m.
Oxalic acid vol.; elast. Turp. V. 42·1.
Alloy 8 B. 32 L. 30 T. m.

Alloy 8 B. 32 L. 40 T. m

322 Alloy 8 B. 32 L. 38 T. m.
Naphtha boils; alloy 8 B. 26 L. 24 T. m., also 8 B. 32 L.
Prussian blue decomposed.
Alloy 8 B. 16 L. 24 T. m.
Oil of turpentine boils 0·86; dens. V. 4·7.
312 Alloy 8 B. 16 L. 22 T. m.
Kinic acid m.
Alloy 8 B. 20 L. 24 T. m.; oil juniper b.
Alloy 8 B. 22 L. 24 T. m.
Rect. petroleum b.
Carb. pot. sat. boils. {Alloys 8 B. 16 L. 10 T. and 8 B. 16 L. 20 T. m.
302 ETHERIFICATION ends; latent heat; ether vap.
Alloy 8 B. 16 L. 8 T. m.; camphilene b. 86; sugar of milk

Asphaltum melts; camphor melts, d. v. 5·31.
Zinc malleable.
Alloy 8 B. 16 L. 12 T. m.
292 Alloy 8 B. 16 L. 16 T. m.
Gypsum converted to plaster.
Sulphuric acid, 1·52 b.
Pyroxanthin m.
Elast A. V. 96·64.

Tin and bismuth, p. æ. melt; succ. acid vol.
pr. steam locomotive boilers.
282 ETHERIFICATION begins.

Bichloride sulphur b.

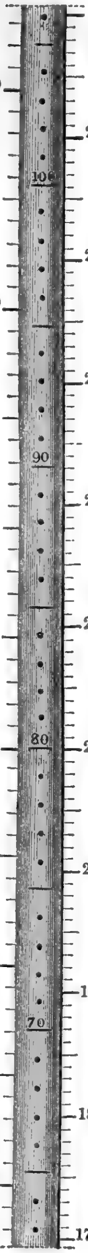
Cholesterine melts.
Elast. A. V. 85·47.
Oil black mustard b.; maleic acid m.
272 Peusyl b. 0·86.

CENTIGRADE.

Chloride benzole m.

Phloridzine solid. Alloy 8 B. 10 L. 8 T. m. 130
Camphoric acid v.
pr. steam, 2·5 at.
Elast. A. V. 69·72.
Sebacic acid m. ; Elast. alch. v. 155·2.
Sat. mur. ammonia boils.
Sat. acet. soda boils.
Pyromeconic acid m.
Elast. A. V. 60·05.
pr. steam, 2 at.
Cinnamic acid m. ; caoutchouc melts. 120
Alloy 5 B. 1 L. 4 T. m.
Sat. nit. soda boils.
Sat. chlor. strontium boils.
Elast. A. V. 51·34.
Syrup boils 86 per cent. ; chlor. calcium sat. boils.
Sat. nit. potash boils ; Elast. A. V. 47·2.
Alloy 8 B. 8 L. 4 T. m.
Chloric ether, 1·227 boils ; pr. steam, 1·5 at.
Elast. A. V. 43·24.
Elacne b. ; Elast. alch. v. 94·1. 110
Phloridzine m.
Elast. A. V. 39·59.
Alloy 8 B. 8 L. 3 T. m.
Oxalhydric acid. b. 1·375.
Water of the Dead Sea boils.
at. carb. soda, chlor. of barium. and chlorate potash boil.
Salicine m. ; nitric acid, 1·16 b.
Sat. chlor., calcium, boracic acid b.
Mur. acid, 1·136 b.
Syrup boils 52 per cent. sugar.
Chlor. aluminum boils ; water boils, bar. 31 213·76.
Glauber salt sat. boils.
c. l. 1 pt. ice ; 4 sulphuric acid ; pr. steam, 1 at. 100
100 air at 32°=137·5.]
Elast. A. V.=30 S. G. 625.] Water boils bar. 29 in.
Chloride nitrogen explodes.
W. B. MADRID.
W. B. EL SATTRE (between Dead Sea and Akabah.)
COMAGILLAS. Mexican Springs.
W. B. GAVARNIE, PYRENEES.
Volcanic mud ; JORULLO, S. AMERICA.
Oxychlorocarbonic ether b.
Elast. ether vap. 166 ; Elast. A. V. 23·64.
W. B. MEXICO.
7,471 ft. el.
W. B. SANTA FÉ DE BOGOTA.
8,730 ft. el. 90
Water boils ; CONVENT ST. BERNARD.
9,734 ft. el.
W. B. FARM OF ANTISANA, Andes, 13,000 ft. el.
Chloric ether b. 1·24.
W. B. source of Oxus, CENTRAL ASIA.
(15,600 ft. elev.)
Elast. A. V. 15·15.
Geyser Springs, Iceland.
Elast. A. V. 14·2.
80
Heat. of fluid. bees'-wax.
Elast. alch. vap. 30 in. S. G. 0·813.

RÉAUMUR.



FAHRENHEIT.

Syrup sat. boils.
Corrosive sublimate volatilised.
Chloride of arsenic b.
Elast. A. V. 74·79.
Margaritic acid ; castor oil m.
Elast. alch. V. 166·1.
Syrup boils 89 per cent. sugar.
262 Sat. tartrate potass boils.
Sat. nitrate potass boils ; heat borne by Sir J. Banks and Dr. [Blagden.
Hydriodic acid boils 1·7 ; also hydrobrom. acid, 1·5.
Elast. A. V. 64·82 ; pimaric acid m.
Sat. acetate soda boils.
Alloy 8 B. 8 L. 6 T. m.
252 Nitric acid 1·42 boils.
Elast. alch. V. 132·3 ; dichl. carbon v.
Benzoine melts ; Hyd. acet. acid boils (Turner).
Elast. A. V. 55·54.
Heavy muriatic ether b.
Elast. alch. V. 118·2.
212 Alloy 8 B. 8 L. 6 T. m.
Quinia m.
Sulphuric acid 1·30 b. ; pyrogallic acid m.
Veratrine and benzamide m.
Accumulated temp. of air, EDINBURGH.
Acet. acid 1·063 boils ; nit. acid 1·30 b.
Sat. mur. ammonia boils.
Syrup boils 84 per cent. sugar.
232 Sulphur melts, d. v. 6·65 ; benzoine m.
Benzoic acid melts, d. v. 4·27.
Silicine m.
Zinc malleable ; heat borne by Delaroche.
Sat. chlor. sod. boils.
Sat. chlor. pot. boils.
Sat. nit. strontia boils.
Sat. phos. soda boils.
222 Muriatic acid 1·017 b. ; Elast. A. V. 36·25.
Accumulated temp. of air, GENEVA.
Asphaltum soft ; iodine melts ; elast. ether V. 240.
Phosphorus distils.
Elast. A. V. 33·09 inches mercury ; grape-sugar m.
Osmic acid volatilised. Sulphocyanic acid b.
Sylvic acid m.
Water boils 1,054 ft. dep. ; selenium melts ; water boils, bar. 31.
Water boils 328 dep. ; W. B. DEAD SEA and SEA OF TIBE- [RIAS.
212 Water boils bar. 30.
Water boils 531 ft. elevation.
Water boils 1,064 ft. elevation ; osmic acid melts.
Water boils 1,600 ft. elevation ; Reikiavik spr.
Water boils 2,138 ft. elevation.
Water boils 2,678 ft. elevation ; alloy 8 B. 6 L. 3 T. m.
Water boils 3,221 ft. elevation.
Water boils 3,766 ft. elevation.
Water boils 4,313 ft. elevation.
Water boils 4 863 ft. elevation.
202 Water boils 5,415 ft. elevation.
Fusible metal. 8 B. 5 L. 3 T. m. ; chloral b. d. v. 5.
Elast. alch. vaps. 53.
W. B. St. Gothard, 6,807 ft. elevation.
W. B. Mt. William, AUSTRALIA, 8,200 ft. el.
Water boils at Quito, 9,341 ft. el.
Sodium melts ; Trinchera springs, S. AMERICA.
192 Water boils summit of Etna, 10,955 ft. el.
Elast. ether vap. 124·8 ; alch. vap. 43·2.
Alcohol b. 0·967, 25 per cent.
Nitric acid 1·522 boils ; alcohol b. 0·958, 30 pr. c.
Ozokerite m.
182 Water boils Mont Blanc summit, 15,630 ft. el.
San Germano Bath, NAPLES.
Starch dissolves ; alch. b. 0·870, 71 per cent.
AIX-LA-CHAPELLE, spr. max. t.
Latent heat, petroleum vap., also oil turp.
Benzole, or benzine, b.
Alcohol boils 0·835, 85 per cent.
Thermal spr., I. LUCON.
Alcohol boils, 0·794, also 0·812, 94 per cent to 100.
172 Naphthaline melts.

CENTIGRADE. RÉAUMUR. FAHRENHEIT.

Pitch melts.

Vapour-bath, FINLAND, max. t.

Perchlor. carbon vap. 1·55.

Helenine m.
Elast. A. V. 9·46 ; ether vap. 80·3.

Starch converted to sugar.

70

Baden Baden Springs, max. t.

CALPEE, INDIES, max. t.
LAGNÈRES DE LUGHON, spr.
Elast. A. V. 7·42, S. G. 0·17 ; ether vap. 67·6.

Albumen opaline.
Elast. A. V. 6·87.
Heat of fluidity spermaceti.

Heat of fluidity sulphur.
Vapour-bath, RUSSIA.
Chloroform, b. d. v. 4·2.
Nitric acid (1·5) 58 pts. water, 12 pts. from 60°. 60
Mariana Springs, S. AMERICA.

Elast. ether, vap. 51·9.

BARBARY, max. t.
Abietic acid m.

Ammonia 0·936 b.
Elast. A. V. 4·2.
OASIS OF MOURZOUK, max. t.

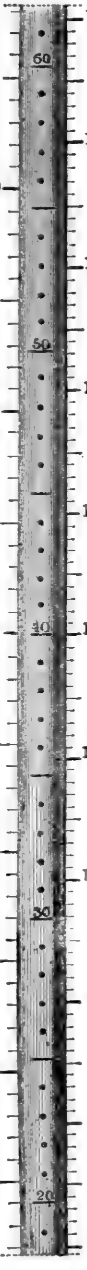
FEZZAN, AFRICA, max. t.
Terchlor. silicon, b.
BAGNÈRES DE BIGORRE, spr.
Amalgam 8 B. 5 L. 2 T. and 3 mercury m. 50
Concent. sulphuric acid evaporates.

Palmitic acid m.

Hamman Ali springs, BARBARY.
PAMPAS, SOUTH AMERICA.

CENTRAL AFRICA, s. t. ; BASSORA, max. t.
PONDICHERRY, max. t.
Chloronaphthalese m.
PHILÆ, EGYPT, CAPE OF GOOD HOPE, max. t.
Myrtle wax m.
SENEGAL, s. t.
BARÈGE, spr.

MADRAS, CAIRO, max. t.
40
Ournartok spring, GREENLAND.
Amylene b. GUADALOUPE, max. t.
PARIS 1793, EQUATOR, max. t.
Eupion b. 0·65.
GUANAXUATO MINES, 1,700 ft. deep, 7,034 ft. el.
MEXICAN MINES, max. t.
STRASBURG, VIENNA, max. t. *Man, min. t.
TEXAS, s. t.
MARTINIQUE, max. t.
STOCKHOLM, max. t.
Consol. mines, CORNWALL, 1,740 ft.
COPENHAGEN, WARSAW, max. t.
EAUX BONNES, Pyrenees.
max. t. of SURINAM.
ROCHAT, spr.
CAIRO, s. t.
IS. MALTA, EGYPT, m. s. t. 30
PONDICHERRY, m. t.
Seychelles, max. t.
Schlangenbad Spa.
CUMANA, m. t.
BRAZILS, m. t. ; BARBARY, m. s. t.
CEYLON, SENEGAL, BATAVIA, m. t.
MADRAS, m. t.
CONGO, MANILLA, BENARES, HAVANNAH, m. t.
BOMBAY, m. t.; ITALY, m. s. t. Date-tree, VERA CRUZ.
Artesian well (200 ft.), BRAZILS, JAMAICA, m. t.
RIO JANEIRO, m. t.
CANTON, MACAO, m. t.
BAGDAD, m. t.
Aldehyde, b. ; CARACCAS, CAIRO, m. t.



172 Ethylic alcohol b.

Elast. ether. vap. 92·8, alch. b. 92 per cent. 0·817.

Elast. A. V. 11·5.

Phosphorus burns violently ; acetic ether b.
Oil of cedar melts, Carlsbad Spa.

Elast. A. V. 10·4.
162 Heat of fluidity lead.

Albumen coagul. ; acetic ether boils ; Pisciarelli springs, [NAPLES.

Kochbrunnen, Wiesbaden.
Stearic acid melts.

Elast. A. V. 8·4.
STEAM-BOATS' ENGINE-ROOM, W. INDIES.
HECLA, earth at summit.
152 Thermal spr., TAJURAH AND SHOA.

White wax melts ; Pyrox. spirit boils.
Wiesbaden Spa ; hydriod. ether b., S. G. 1·92.

Plombières spr.

Ambergris m. Peroxide Chlor. explodes.
Ischia springs, NAPLES ; Leuker spr. 5,000 ft. el.
Aix-la-Chapelle Spa.
142 Chloroform boils.
Yellow wax melts.
Ammonia 0·94 boils : pyroxylic sp. b. 0·832 ; elast. A. V. 5·74.

Muriatic acid 1·19 boils.

UPPER EGYPT, in a tent ; Arles spr.
Elast. A. V. 5·14.

Margaric acid melts.
Formic ether b., S. G. 915.
132 Acetone boils (pyroacetic spirit).
Oleine boils.
Potassium melts ; vapour-bath ends.
Berger in vapour-bath 12 min.

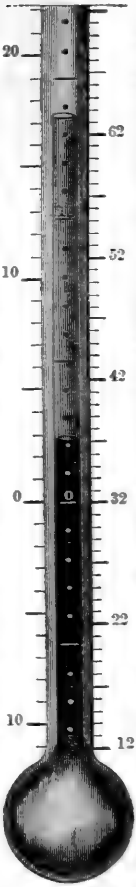
Jorullo springs, S. AMERICA ; MYNPOOREE, max. t.
Sands at S. Fernando, S. AMERICA, air 101°.
Stearic and oleic acids (mixed) melt, BELBEIS, EGYPT.
Mutton-suet melts ; Cauterets spr.
Katakekaumene spr.
122 Styracine m.

Stearine and cetine melt ; myristic acid m. ; elast. A. V. 3·38.

Bisulphide carbon b.
Bath springs, max. t. ; supposed depth 3,350 ft. *Lark.
Bromine boils ; hot pump at Bath, dens. Br. V. 5·54.
Ems Spr. max. t.
King's bath at Bath ; laurine m.
Sal-ammoniac boils 0·91.
112 Spermaceti melts ; Muscat springs.
*Duck, *guinea-fowl, *raven.
*Pigeon ; PEKIN, max. t. ; Vichy spr. max. t.
C. fowl ; Cross bath at Bath.
*Birds, 108°, 111°.

Cold-blooded animals die.
Temp. for incubation ; elast. ether vap. 30 inches.
*Sheep and pig, owl ; phosphorus melts.
*Ape, dog, goat ; artificial incubation.
102 *Animals, man, max. t. ; ox, infant child.
*Squirrel, rat, cat, jackal, panther.
*Bat, hare, tiger, horse, elephant ; elast. A. V. 1·86.
Warm bath ends, vapour-bath commences.
*Temp. man, kite (birds).
Blood-heat, hedgehog, dormouse.
{Tepid bath ends, warm bath begins.
{Ether boils 0·724 ; dens. V. 2·58.
Oil of roses melts ; cococic acid m.
92 PUTREFACTION rapid. Old palm oil m.
VALENCIANA MINE, MEXICO ; Grenelle well, 1,791 ft.
Elast. A. V. 1·36 ; Poldice mine.
Tallow melts.
ACETOUS FERMENTATION.
PETERSBURG, max. t. ; oil nutmegs m.
Kaisareyeh, ASIA MINOR, 4,200 ft. el.
Tepid bath begins, Cacao butter m. [1,428 ft.
*Tortoise, Cornish mines, Buxton Spa, DOLCOATH MINE,
*Serpents, SEA EQUATOR, 83·7.
82 Nitrous acid 1·42 boils ; Buxton bath, ALGIERS, s. t.
EQUATOR, m. t. 81·5 ; *oyster, snail (Tropics).
Phosphorus luminous in pure oxygen ; NAPLES, s. t.
Prussic acid boils, 0·69. [El. A. V. 1
Frog, shark, flying-fish, scorpion (Tropics).
Insects, silk-worms hatched, germination.
Bristol Spa, temp. wasp.
MEXICAN MINES, 1,650 ft. deep ; SYDNEY, s. t.
Glowworm, cricket ; PRUSSIAN MINES, 880 ft.
Artesian well, GRENELLE, 1,300 ft. deep.
72 MONKWEARMOUTH MINE, 1,500 ft. deep.

CENTIGRADE. RÉAUMUR. FAHRENHEIT.



SANTA CRUZ, TENERIFFE.
Hypon. ether b.; iodine vaporised.
Aldehyd. boils; Elast. A. V. 0·721.
Cotton-tree; ALGIERS, m. t.
Gipps' Land, AUSTRALIA, MALTA, m. t.
CAPE OF GOOD HOPE, FUNCHAL, m. t.
Elast. A. V. 0·616.
Cultivation of vine ends.

ENGLAND, m. s. t. 62·6.
TOULON, m. t.

Elast. A. V. 0·52; ROME, NICE, m. t.
VILLE I. (max. t.) NISMES, GENOA, LUCCA, m. t.
PERPIGNAN, MONTPELIER, m. t.
Waterford mines, 774 ft. dep., MARSEILLES, m. t.
BON, BOLOGNA, BORDEAUX, AIX, VENICE, m. t.
LYONS, VERONA, MILAN, m. t.
PAU, m. t. LOWER EGYPT, w. t.
AMSTERDAM, PEKIN, NEW YORK, m. t.
NANTES, ST. MALO, m. t.
MALTA, w. t.; m. t. BRUSSELS.
PENZANCE, m. t.
Cultivation of vine begins, PARIS, LONDON, m. t.
Elast. A. V. 0·37, S. G. 0·1.
Salt mines CRACOW, 730 ft.; muriatic acid, 40 at Liq.}
Sulphur. hyd. 17 at.; ammonia, 6·5 at. }
EDINBURGH, BERLIN, DUBLIN, m. t.
INVERNESS, COPENHAGEN, m. t.
COVE CORK, w. t., m. t. TORONTO.
MONT PERDU, PYRENEES, 11,265 ft. el.
UPSAL, STOCKHOLM, QUEBEC, m. t.
CANADA, m. t. Elast. A. V. 0·263.
CHRISTIANIA, DRONTHEIM, m. t.
Hybernation of animals.
PETERSBURG, m. t.; Etna sum. 10,955 ft. el.
KASAN, m. t.
POLAR SEAS, 360 ft. deep.
BERGEN, PADUA, COLUMBIA, r. w. t.
SCOW, m. t.; oils freeze. ALTEN, NORWAY, m. t.
onic acid liq. 36 at., N.CAPE LAPLAND, LABRADOR.
Elast. A. V. 0·2 inch. S. G. 005.
CUMBERLAND, HO. N. A. m. t.
Earth, YAKUTSK, 350 to 382 ft. dep.
CHIMBORAZO, 18,500 ft. el.

MONT BLANC, 15,630 ft.
HIMALAYAS, 18,000 ft. el.
IRKUTSK, m. t.
SIBERIA, m. t.

Earth YAKUTSK, 77 ft. dep.

AIR m. t. POLAR SEA.

NOVA ZEMBLA, m. t., PORT ENTERPRISE, w. t.

Anhyd. sulphurous acid boils.
Oil of turpentine freezes.

west natural temperature at YAKUTSK, in Siberia.
−72=34° below this scale.

CENTIGRADE TO FAHRENHEIT.

Above Ice.
$C \times 1{\cdot}8+32$

Between Ice and Zero.
$32\ (C \times 1{\cdot}8)$

Below Zero.
$C \times 1{\cdot}8-32$

Water boils in vacuo, *crab.
VINOUS FERMENTATION, butyrine melts, CAIRO
DURHAM COAL MINES, 900 ft. [WELL, 210 ft. deep.
Cocoa-nut-oil liquid, Matlock bath, Grotto del Cane.
CORDILLERAS, ANDES, m. t. 5,000 ft. el.
Matlock springs, CUMBERLAND COAL MINES, 600 ft.
SAXON MINES, 1,246 ft.; Bakewell springs. [mander.
{MADEIRA, m. w. t.; air centre of Atl. waters of the Sea-
{NAPLES, m. t. Temp. for sick rooms.
DEEP MINES, EUROPE; sea-bank of Aguilas.
PARAMATTA, N S. W. m. t.; LEIERS, w. t.; sea Azores.
Fluoric acid boils, anhyd. chlorine liqfd. 4 at.
Acetic acid cryst.; Puy de Dôme, 3,600 ft.
CAIRO, w. t., MINES OF BRITTANY 500 ft., BERGEN, s. t.
*Trout, MEDITERRANEAN SEA, 2,000 ft.
Vaucluse Fountain, 360 ft. el.
Artesian well VIENNA, 200 ft.; Hanwell, 290 ft.
Camphor floats, Elast. A. V. 0·44.
PIC DU MIDI, 9,560 ft.; JERSEY, m. t.
Oil of aniseed solid, muriatic ether boils.
CLERMONT, m. t.; Columbia r. m. t. [begins.
ITALY, m. w. t.; VIENNA, m. t. 50·5; PUTREFACTION
Liq. ammon. boils. Sat. at. 32; STRASBURG, m. t.
WARSAW, BERNE, m. t. [PRAGUE, GENEVA, m. t.
TENERIFFE PEAK, 12,072 ft. el.
ZURICH, GOTTINGEN, LABRADOR, s. t.
Sulphurous acid liqfd. 2 at.; protox. nit. 50 at.; Cyanogen, 30
SEA EQUATOR, 2,400 ft. deep. [at.
DEEP SEA, common springs, HASTINGS, w. t.
LAKE OF GENEVA, 1,000 ft. deep; ROME, w. t.

LAKE LUCERNE, 650 ft. deep; *beetle, PAU, w. t.
St. acid freezes; CARPATH. MOUNTAINS; mercury evap.
CAPE HORN SURFACE OF SEA; max. density of water.
EDINBURGH, w. t. ENGLAND, m. w. t. 37·8. [w. t.
Alcohol boils in vacuo; NOVA ZEMBLA, s. t., SHETLAND,
Fixed oils freeze; SOUTH SEA, 12,420 ft. deep.
CAPE HORN SEA, 5,400 ft. deep.
Mount Argæus, ASIA MINOR, 10,300 ft. el.
ICE, chlor. wr. freezes, sc. ad. 3rd, hydr. freezes.
POLAR SEA, 2,300 ft. deep; earth YAKUTSK, 382 ft. deep.
Milk freezes.
CARTHAGENA, SPAIN, w. t.
Salt water freezes, 1·026; vinegar freezes; formic acid freezes.
Earth YAKUTSK, 217 ft. deep.
JUNGFRAU, summit, 12,725 ft.
Blood freezes, earth YAKUTSK, 119 ft. deep.
Elain freezes, HECLA (Air) at summit, 5,110 ft. el.
Oil bergamot freezes.
Kakodyl solid.
Oil cinnamon freezes, oleic acid (castor oil) freezes.
Wine freezes.

Earth YAKUTSK, 50 ft. dep.
GULF BOTHNIA AIR, m. w. t.; Great Bear Lake, m. t.
AIR 23,000 ft. elevation above PARIS (at surface 87°).

Salt water freezes, 1·104.
RUSSIA, m. w. t.
Prussic acid cryst. 0·69 S. G.
ALTEN, NORWAY, w. t.
N. POLE, m. t. 13 below zero (calc).
Mercury freezes. } 40° below zero, m. w. t. at NOVA
Ether boils in vacuo. } ZEMBLA and YAKUTSK.
Carbonic acid freezes 148° below zero.
Lowest artificial cold obtained by Natterer, −220° Fahr.

FAHRENHEIT TO CENTIGRADE.

Above Ice.
$\frac{F-32}{1\cdot8}$

Between Ice and Zero
$\frac{32-F}{1\cdot8}$

Below Zero.
$\frac{F+32}{1\cdot8}$

ABBREVIATIONS.

m. melts. m. t. mean temperature. w. winter. s. summer. at. atmosphere. b. boils. v. volatilised. liq. liquid. liqfd. liquefied. Ad. acid. max. maximum. min. minimum. Sol. solution. W. B. water boils. El. elevation. In reference to fusible alloys: B. bismuth. T. tin. L. lead. pr. pressure. dep. depression. I. Island. Vapr. Vapour. Elast. elasticity. Fluid. Fluidity. Alch. Alcohol. Turp. Turpentine. dens. density. In regard to places mean temp. is implied where *not* expressly stated. r. river. spr. spring. fr. freezes. A. V. Aqueous vapour. d. v. density of vapour. S. G. specific gravity. The Elasticity of Vapours is given in inches of Mercury.

TEMPERATURES ABOVE THE SCALE.

Tin and Cadmium m. 442°. Tempered steel (straw colour) 460°. Sulphc. ad. 1·78 b. 467°. Bismuth m. 476°. Tempered steel (brown) 500°. Fixed oils b. 520°. Tempered steel (red and purple) 550°. The same (blue) 600°. Lead m. 612°. Sulphc. ad. 1·85 b. 648°. Mercury b. 662°. Zinc m. 680°. Gunpowder explodes 700°. Antimony m. 810°. Red heat 980°. Flint glass m. 1000°. Heat of common fire 1141°. Brass m. 1869°. Silver m. 1873°. Copper m. 1996°. Gold m. 2016°. Cast iron 2786°. Pure iron and platina m. 3280°. Wind furnace white heat 3300°.

sion of the degrees of one scale into those of another, comparative tables, which however, convey no information beyond the bare fact of the correspondence of certain degrees. In this table, the attempt has been made to make it convey information on numerous interesting points, connected with temperature in relation to climatology, physical geography, chemistry, and physiology.

There is another advantage which a table of this kind must possess over those hitherto published in works on chemistry. In the latter, the degrees on one scale only run in arithmetical progression, while the corresponding degrees on the other scale are necessarily given in fractional or decimal parts, and at unequal intervals. Thus, in some of the best works on chemistry, a comparative table is printed, which is only fitted for the conversion of the Centigrade into Fahrenheit degrees, so that a person wishing to convert the Fahrenheit into Centigrade degrees, would have to revert to one of the old formulæ of conversion. This process must also be adopted whenever the Centigrade degrees are given in decimal parts, for many of the tables published in English works wrongly assume that the Centigrade degrees are always given in whole numbers. The present table renders such calculations unnecessary, since the value of any degree, or of any part of a degree on one scale, is immediately found on the other, by looking at the degree in a parallel line with it. The main divisions will, it is believed, be found perfectly accurate. In single degrees a little inequality may be occasionally detected; but the error has not been found to be such as to affect the calculated temperature.

Although the Fahrenheit and Centigrade scales are the two which are chiefly used in Europe, it has been thought advisable to carry out the parallel degrees of Réaumur's scale, by dots on the drawing of the tube. This table, therefore, comprises in itself six distinct tables, assuming the necessity for each scale to be represented in whole degrees, with the additional advantages: 1st, that the space occupied is smaller; and 2nd, the value of any fractional part of a degree on one may be at once determined on the other two scales.

It is extraordinary, considering the great advances which have been recently made in physical science, and in the manufacture of philosophical instruments, that the makers of thermometers should still adhere to the old and absurd practice of marking on the Fahrenheit scale, the unmeaning words Temperate, Summer-heat, Blood-heat, Fever-heat, Spirits boil, &c., when the instrument might be easily made to convey a large amount of information in respect to climate, as it is dependent on temperature.

It will be seen that the table here published ranges from 12° to 374° Fahrenheit., from — 11° to + 190 Centigrade, and from — 9° to + 152° Réaumur.

It will be only necessary to state generally those facts which the table is intended to illustrate. They will be found arranged opposite to their respective degrees, either on the Centigrade or Fahrenheit side, according to the space afforded.

The facts connected with temperature placed on the scale may be arranged under the heads of Climatology, Physical Geography, Chemistry, and Physiology.

Climatology. 1. The mean temperatures of the principal countries, towns, and cities in the world, with the maxima and minima, as well as the mean summer and winter temperature of some of the most important localities.

2. The maximum degrees of heat and the minimum degrees of cold observed on the surface of the globe, including the accumulated temperatures of air at Edinburgh and Geneva.

Physical Geography. 1. The temperature of the atmosphere, as observed on the summits of the principal mountains of the Old and New World, with the respective elevations attached; at the sea-level in various latitudes, from the Arctic to the Antarctic Seas, as well as in deep mines and other excavations in Europe and America.

2. The temperature of the ocean at the surface, and at various depths to 12,420 feet, including the temperature of the Polar Seas, of the Mediterranean, Atlantic and Pacific, with the temperature of the Gulf Stream.

3. The temperature of the waters of lakes and rivers at various depths, with the respective fathomings attached.

4. The temperature of the strata of the earth at various depths, observed in some of the deepest mines in the Old and New World.

5. The temperature of the water raised in Artesian wells in Europe from depths varying from 250 to 1,794 feet.

6. The temperature of the principal thermal springs and baths observed in Europe, Africa, the West Indies, and South America.

7. The temperature at which water boils at all the elevated and inhabited spots in the world, including the summits of the mountains of Switzerland, South America, and Central Asia; the boiling point for all elevations up to 5,415 feet, and for 1,054 feet depression below the level of the sea.

Chemistry. 1. The evaporating, boiling, fusing, melting, subliming, and congealing points of the principal solids and liquids in chemistry, from 12° to 374° Fahrenheit, from — 11° to + 190° Centigrade and from — 9 to + 152° Réaumur, including the boiling points of the saturated solutions of numerous salts, and the melting points of a large number of alloys.

2. The temperature for fermentation of various kinds, malting, putrefaction, etherification, and other chemical processes.

3. The boiling points of alcohol and acids of various specific gravities, with the respective densities of their vapours.

4. The pressure or elastic force of the vapour of water, alcohol, oil of turpentine, and ether, at various temperatures.

5. The temperatures, with the corresponding pressures, required for the liquefaction of the gases.

6. The temperature for the explosion and ignition of fulminating and combustible substances.

Physiology. 1. The maximum degrees of natural and artificial heat, and minimum degrees of cold, borne by man and animals.

2. The temperature of the body in man, mammalia, birds, reptiles, fishes, and insects.

3. The temperature at which hybernation takes place in certain animals.

4. The temperature for the germination of seeds, incubation, the artificial hatching of the ova of birds, fishes, and insects.

5. The temperature for the growth of the sugar-cane, date, indigo, cotton-tree, and for the cultivation of the vine.

6. The temperature for warm, tepid, and vapour-baths; the vapour-baths of Russia and Finland.

THERMOMETER, *Self-registering, by Photography.* The first person who in this country proposed to apply photography, and actually did apply it, as a means of registering the movements of the mercury in the thermometer and barometer, and also for registering the variations in the magnetic intensity, was Mr. Thomas B. Jordan, at that time Secretary to the Royal Cornwall Polytechnic Society. The results of this gentleman's methods and the description of his plans will be found in the *Sixth Annual Report of the Royal Cornwall Polytechnic Society for* 1838.

Mr. Ronalds, of the Kew Observatory, also devised an arrangement for employing photography as the means of registering meteorological inventions, and subsequently Mr. Charles Brooke perfected a method which is now generally adopted.

THERMOSTAT is the name of an apparatus for regulating temperature, in vaporisation, distillations, heating baths or hothouses, and ventilating apartments, &c.; for which Dr. Ure obtained a patent in the year 1831. It was, in fact, a differential thermometer, similar in construction to Brady's metallic thermometer.

THIALDINE. $C^{12}H^{13}NS^{4}$ ($\mathbf{C^{6}H^{13}NS^{2}}$). A curious alkaloïd, formed by the action of sulphuretted hydrogen on aldehyde ammonia.

THIEVES' VINEGAR. (*Le Vinaigre des quatre Voleurs*, Fr.) See AROMATIC VINEGAR.

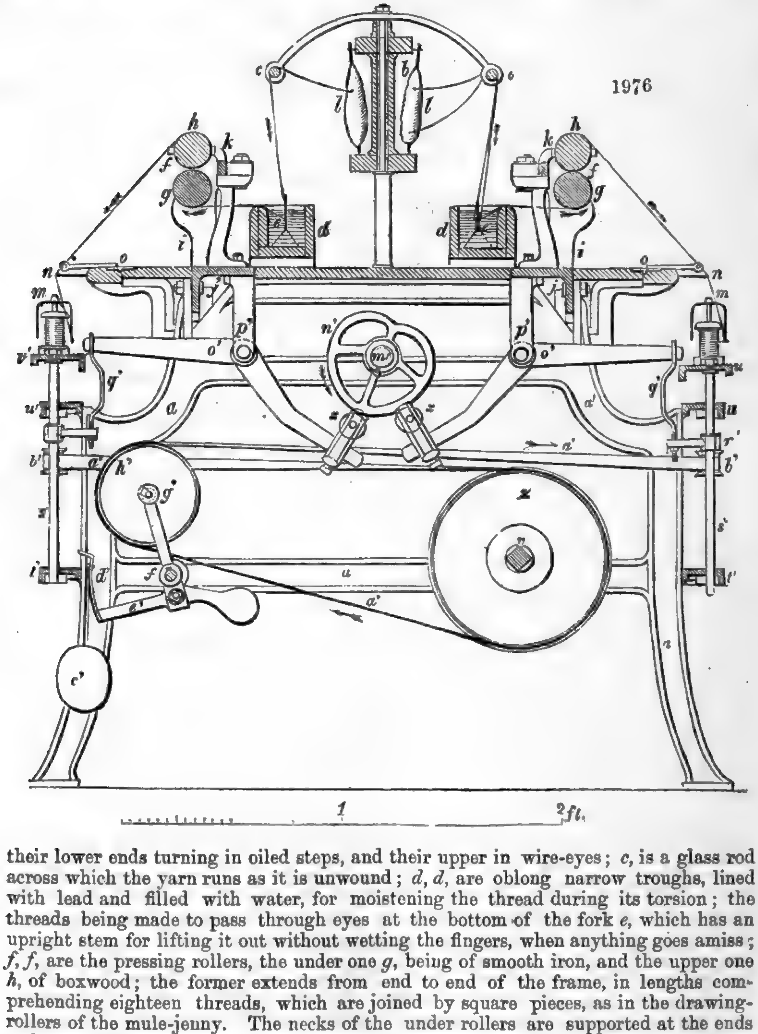
THIMBLE. (*Dé à coudre*, Fr.; *Fingerhut* (*fingerhat*), Ger) This is a small truncated metallic cone, deviating little from a cylinder, smooth within, symmetrically pitted on the outside with numerous rows of indentations, which is put upon the tip of the middle finger of the right hand, to enable it to push the needle readily and safely through cloth or leather, in the act of sewing. This little instrument is fashioned in two ways: either with a pitted round end, or without one; the latter, called the open thimble, being employed by tailors, upholsterers, and, generally speaking, by *needlemen.* The following ingenious process for making this essential implement, the contrivance of MM. Rouy and Berthier, of Paris, has been much celebrated, and very successful. Sheet-iron, one twenty-fourth of an inch thick, is cut into strips, of dimensions suited to the size of the intended thimbles. These strips are passed under a punch-press, whereby they are cut into disks of about 2 inches diameter, tagged together by a tail. Each strip contains one dozen of these blanks. A child is employed to make them red-hot, and to lay them on a mandril nicely fitted to their size. The workman now strikes the middle of each with a round-faced punch, about the thickness of his finger, and thus sinks it into the concavity of the first mandril. He then transfers it successively to another mandril, which has five hollows of successively increasing depth; and, by striking it into them, brings it to the proper shape.

A second workman takes this rude thimble, sticks it in the chuck of his lathe, in order to polish it within, then turns it outside, marks the circles for the gold ornament, and indents the pits most cleverly with a kind of milling tool. The thimbles are next annealed, brightened, and gilt inside, with a very thin cone of gold-leaf, which is firmly united to the surface of the iron, simply by the strong pressure of a smooth steel mandril. A gold fillet is applied to the outside, in an annular space turned to receive it, being fixed by pressure at the edges, into a minute groove formed on the lathe.

Thimbles are made in this country by means of moulds in the stamping machine. See Stamping of Metals.

THORINUM or **THORIUM.** A rare metal, discovered in 1828 by Berzelius in the Norwegian mineral *thorite*, which contains about 57 per cent. of thorina, the oxide of this metal, and where it is associated with the oxide of iron, lead, manganese, tin, and uranium, besides earths and alkalis. None of the compounds of thorinum find any use in the arts.

THREAD MANUFACTURE. The doubling and twisting of cotton or linen yarn into a compact thread for weaving bobbin-net, or for sewing garments, is performed by a machine resembling the throstle of the cotton-spinner. *Fig.* 1976 shows the thread-frame in a transverse section, perpendicular to its length. *a*, is the strong framing of cast iron; *b*, is the *creel*, or shelf, in which the bobbins of yarn *l*, *l*, are set loosely upon their respective skewers, along the whole line of the machine, their lower ends turning in oiled steps, and their upper in wire-eyes; *c*, is a glass rod across which the yarn runs as it is unwound; *d*, *d*, are oblong narrow troughs, lined with lead and filled with water, for moistening the thread during its torsion; the threads being made to pass through eyes at the bottom of the fork *e*, which has an upright stem for lifting it out without wetting the fingers, when anything goes amiss; *f*, *f*, are the pressing rollers, the under one *g*, being of smooth iron, and the upper one *h*, of boxwood; the former extends from end to end of the frame, in lengths comprehending eighteen threads, which are joined by square pieces, as in the drawing-rollers of the mule-jenny. The necks of the under rollers are supported at the ends and the middle, by the standards *i*, secured to square bases *j*, both made of cast iron.



1976

The upper cylinder has an iron axis, and is formed of as many rollers as there are threads; each roller being kept in its place upon the lower one by the guides *k*, whose vertical slots receive the ends of the axis.

The yarn delivered by the bobbin *l*, glides over the rod *c*, and descends into the trough *d e*, where it gets wetted; on emerging, it goes along the bottom of the roller *g*, turns up so as to pass between it and *h*, then turns round the top of *h*, and finally proceeds obliquely downwards, to be wound upon the bobbin *m*, after traversing the guide-eye *n*. These guides are fixed to the end of a plate which may be turned up by a hinge-joint at *o*, to make room for the bobbins to be changed.

There are three distinct simultaneous movements to be considered in this machine: 1, that of the rollers, or rather of the under roller, for the upper one revolves merely by friction; 2, that of the spindles *m*, *s′*; 3, the up-and-down motion of the bobbins upon the spindles.

The first of these motions is produced by means of toothed wheels, upon the right hand of the under set of rollers. The second motion, that of the spindles, is effected by the drum *z*, which extends the whole length of the frame, turning upon the shaft *v*, and communicating its rotatory movement (derived from the steam-pulley) to the whorl *b′* of the spindles, by means of the endless band or cord *a′*. Each of these cords turns four spindles, two upon each side of the frame. They are kept in a proper state of tension by the weights *e′*, which act tangentially upon the circular arc *d*, fixed to the extremity of the bell-crank lever *e′ f′ g′*, and draw in a horizontal direction the tension pulleys *h*, embraced by the cords. The third movement, or the vertical traverse of the bobbins, along the spindles *m*, takes place as follows:—

The end of one of the under rollers carries a pinion, which takes into a carrier wheel that communicates motion to a pinion upon the extremity of the shaft *m′*, of the heart-shaped pulley *n′*. As this excentric revolves, it gives a reciprocating motion to the levers *o′*, *o′*, which oscillate in a vertical plane round the points *p′*, *p′*. The extremities of these levers on either side act by means of the links *q′*, upon the arms of the sliding sockets *r′*, and cause the vertical rod *s′*, to slide up and down in guide-holes at *t′*, *u′*, along with the cast-iron step *v′*, which bears the bottom washer of the bobbins. The periphery of the heart-wheel *u′*, is seen to bear upon friction wheels *x*, *x′*, set in frames adjusted by screws upon the lower end of the bent levers, at such a distance from the point *p′*, as that the traverse of the bobbins may be equal to the length of their barrel.

By adapting change pinions and their corresponding wheels to the rollers, the delivery of the yarn may be increased or diminished in any degree, so as to vary the degree of twist put into it by the uniform rotation of the drum and spindles. The heart-motion being derived from that of the rollers, will necessarily vary with it.

Silk thread is commonly twisted in lengths of from 50 to 100 feet, with hand reels, somewhat similar to those employed for making ropes by hand.

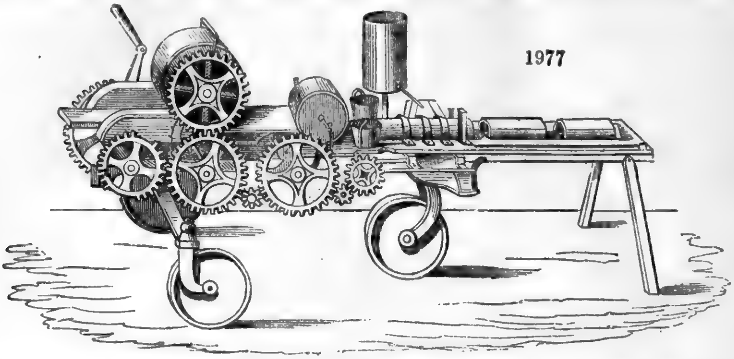
THUYA OCCIDENTALIS. A coniferous tree, from which is obtained a yellow body, *Thuyin*, which is probably identical with *Quercitrin.*

TILE ORE. (*Ziegelerz*, Ger.) An earthy variety of red oxide of copper.

TILES. Tile-manufacture is a very comprehensive term, embracing the following varieties:—Paving bricks or tiles, oven-tiles, foot tiles, plain tiles, pan tiles, hip tiles, ridge tiles, circulars, drain tiles, &c.

The clay used for making tiles is purer and stronger than that used for making bricks. When the clay is too strong, that is, too adhesive, it is mixed with sand before passing it through the pug-mill. As a usual practice the clay is *weathered*; this is effected by spreading it out in layers of about two inches in thickness during the winter, and each layer is allowed the benefit of at least one night's frost before the succeeding layer is put over it. This *weathering* is sometimes effected by exposing the layers to sunshine, which is said to answer equally well with frost. What this weathering does is by no means clear: it is said 'to open the pores of the clay.' We believe that what really takes place is, that under the influences to which it is exposed, the particles break up into smaller particles, and that we have the clay in a more finely comminuted state. The next process is that of *tempering*. After the clay has been allowed to 'mellow, or ripen,' in pits, under water, it is passed through the pug-mill and well kneaded or tempered. It is then *slung*, that is, cut into slices with a string; during which process the stones fall out, or are removed by the hand; it is then ready for the operation of moulding. This may be performed by hand, or by any one of the many machines which have been devised.

Fig. 1977 shows Mr. Hunt's machine for making tiles. It consists of two iron cylinders, round which webs or bands of cloth revolve, whereby the clay is pressed into a slab of uniform thickness, without adhering to the cylinders. It is then carried over a covered wheel, curved on the rim, which gives the tile the semi-cylindrical or other required form; after which the tiles are polished and finished by passing through three iron moulds of a horse-shoe form, as shown in the centre of the cut, while they are at the same time moistened from a water cylinder placed above them.



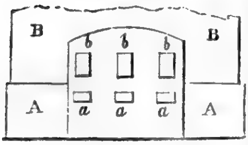
1977

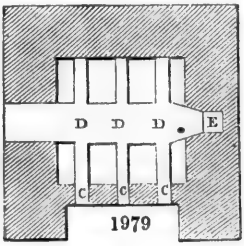
The tiles are next cut off to such lengths as are wanted, and carried away by an endless web, whence they are transferred by boys to the drying shelves.

Flat tiles, for sole pieces to draining tiles, are formed in nearly the same manner, being divided into two portions while passing through the moulds; the quantity of clay used for one draining tile being as much as for two soles.

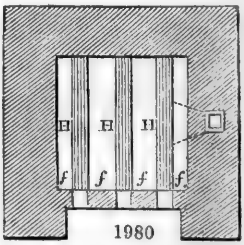
By hand, the work is divided between a moulder and a rough moulder. The latter, a boy, takes a piece of clay and squares it up, that is, beats it up into a slab nearly the shape of the mould, and about 4 inches thick, from which he cuts off a thin slice the size of a tile, and passes it to the moulder. The moulder sands his stock-board, and, regulating the thickness of the tile by four pegs, on which the mould is placed, he puts the piece of clay with which he is supplied into the mould; he then smooths the surface with his very wet hands, removes the superfluous clay, and moulds it into a curved shape. They are then placed to dry, with the convex side uppermost; when half-dry the tiles are taken out one by one, placed on the *thwacking* frame, and beaten with the thwacker to produce the required shape; when dry they are kilned.

1978





1979



1980

The following plan of a furnace, or kiln, for burning tiles has been found very convenient:—

Fig. 1978, front view, A A, B B, the solid walls of the furnace; *a a a*, openings to the ash-pit, and the draught-hole; *b b b*, openings for the supply of fuel, furnished with a sheet-iron door. *Fig.* 1979, plan of the ash-pits and air-channels C C C. The principal branch of the ash-pit D D D, is also the opening for taking out the tiles, after removing the grate; E, the smoke-flue. *Fig.* 1980, plan of the kiln seen from above. The grates, H H H. The tiles to be fired are arranged upon the spaces *f f f f*.

Of late years the manufacture of encaustic tiles and tesseræ for tesselated pavements has been greatly improved by Messrs. Minton of Stoke-upon-Trent, and Messrs. Maw and Co. of Broseley in Shropshire. The production of such tiles by Prosser's patent is fully described under ENCAUSTIC TILES.

TILTING OF STEEL. See STEEL.

TIN. (*Étain*, Fr.; *Zinn*, Ger.) *Symb.* Sn; *At. wt.* 118. This metal, in its pure state, has nearly the colour and lustre of silver. In hardness it is intermediate between gold and lead; it is very malleable, and may be laminated into foil less than the thousandth of an inch in thickness; it has an unpleasant taste, and exhales on friction a peculiar odour; it is flexible in rods or straps of considerable strength, and emits in the act of bending a crackling sound, called the 'creaking of tin,' as if sandy particles were intermixed. A small quantity of lead, or other metal, deprives it of this characteristic quality. Tin melts at 442° Fahr., and is very fixed in the fire at higher heats. Its specific gravity is 7·29. When heated to redness with free access of air, it absorbs oxygen with rapidity, and changes first into a pulverulent grey oxide, and by longer ignition into a yellow-white powder, called '*putty* of tin.' This is the peroxide, consisting of 100 parts of metal and 27·2 of oxygen.

Tin has been known from the most remote antiquity. It is probably mentioned in the Books of Moses; and the ships of Tarshish appear to have brought this metal from islands eastward of the Persian Gulf. The Phœnicians carried on a lucrative trade in it with Spain and Cornwall.

The earliest navigators appear to have taken tin from the east and from the west to supply the wants of Egypt and of Greece. That the Phœnicians, with whom, in those days, the maritime trade of the world rested, collected tin from our own islands is certain; at the same time it is highly probable that the Indian islands were another source from which they obtained this metal in considerable quantities.

'*Kassiteros*,' says Humboldt, 'is the ancient Indian Sanskrit word *Kastira*; *Zinn* in German, *Den* in Icelandic, *Tin* in English, and *Tenn* in Swedish, is in the Malay and Javanese language *Timah*, a similarity of sound which reminds us of that of the old German word *Glessum* (the name given to transparent amber) to the modern *Glas*, glass. The names of articles of commerce pass from nation to nation, and become adopted into the most different languages. Through the intercourse which the Phœnicians, by means of their factories in the Persian Gulf, maintained with the east coast of India, the Sanskrit word *Kastira* became known to the Greeks, even before Albion and the British Cassiterides had been visited.'

The Cassiterides, or Tin Islands, have been supposed to be, by some, the Islands of Scilly. This idea has been far too hastily adopted, seeing that the Scilly Islands produce no tin. In all probability this name was given by the Phœnicians to the whole of the western promontory of Cornwall, the only part of this country with which they were acquainted, the name being without doubt derived from the *Kassiteros* of the East.

There are only two ores of tin: the peroxide, tin-stone, or *Cassiterite*; and tin pyrites, sulphide of tin, or *Stannine*: the former of which alone has been found in sufficient abundance for metallurgic purposes. The external aspect of tin-stone has nothing very remarkable. It occurs sometimes in twin crystals; its lustre is adamantine; its colours are very various, as white, grey, yellow, red, brown, black; specific gravity, 6·9 at least; which is, perhaps, its most striking feature. It does not melt by itself before the blowpipe, but is reducible in the smoky flame or on charcoal. It is insoluble in acids. It has somewhat of a greasy aspect, and strikes fire with steel.

This ore has been found in but a few countries in a workable quantity. Its principal localities are, Cornwall, Bohemia, and Saxony, in Europe; and Malacca, Banca, and Billiton, in Asia, and Australia. The tin mines of the Malay Peninsula lie between the 10th and 6th degrees of south latitude. The mines in the island of Banca, to the east of Sumatra, were discovered in 1710. Small quantities occur in Galicia in Spain, the department of Haute-Vienne in France, and in the mountain-chains of the Fichtel and Riesengebirge in Germany. The columnar pieces of pyramidal tin-ore from Mexico and Chile are found in the alluvial deposits. Vast deposits of tin-stone have recently been discovered in Queensland and New South Wales, where the stream-tin is now being actively worked. It has also been found at Mount Bischoff in Tasmania. Some tin has been recently worked in Peru (1874).

The county of Cornwall is the most important mineral district of the United Kingdom for the number of its metalliferous minerals, many of which are not found in any other part of the island. At a very early period of our history mines were worked around the sea-coasts of Cornwall: of which the evidences are still to be seen at Tol-pedden-Penwith, near the Land's End; in Gwennap, near Truro; and at Cadgwith, near the Lizard Point. The traditionary statements, that the Phœnicians traded for tin with the Britons in Cornwall, are very fairly supported by corroborative facts; and it is not improbable that the Ictes, or Iktis, of the ancients was St. Michael's Mount, near Penzance, and other similar islands on the coast.

In the reign of King John the mines of the western portion of England appear to have been principally in the hands of the Jews. The modes of working must have been very crude, and their metallurgical processes exceedingly rough. From time to time remains of furnaces, called *Jews' houses*, have been discovered, and small blocks of tin, known as *Jews' tin*, have not unfrequently been found in the mining localities.

Till a comparatively recent date, tin was the only metal which was sought for; and in many cases the mines were abandoned when the miners came to the '*yellows*,' that was the yellow sulphide of copper. A great quantity of tin has been produced by 'streaming' (as washing the *débris* in the valleys is termed); and this variety, called 'stream-tin,' produces the highest price in the market. Very little stream-tin is now obtained.

The Cornish ores occur—1, in small strata or veins, or in masses; 2, in congeries of small veins; 3, in large veins; and 4, disseminated in alluvial deposits, as described.

The stanniferous small veins, or thin flat masses, though of small extent, are sometimes very numerous, interposed between certain rocks, parallel to their beds, and are commonly called tin-floors. In the mine of Bottalack a *tin-floor* has been found in the killas (a schistose rock), thirty-six fathoms below the level of the sea; it is about a foot and a half thick, and occupies the space between a principal vein and its ramification; but there seems to be no connection between the *floor* and the great vein.

2. *Stockwerks*, as the Germans term the disseminated masses, occur in granite and in the felspar porphyry, called in Cornwall *elvan*. The most remarkable of these, in the granite, is at the tin-mine of Carclase, near St. Austell. The works are carried on in the open air, in a friable granite, containing felspar—*kaolin*, or china-clay, which is traversed by a great many small veins, composed of tourmaline, quartz, and a little tin-stone, that form black delineations on the face of the light-grey granite. The thickness of these little veins rarely exceeds 6 inches, including the adhering solidified granite, and is occasionally much less. Some of them run nearly east and west, with an almost vertical dip; others, with the same direction, incline to the south at an angle with the horizon of 70 degrees.

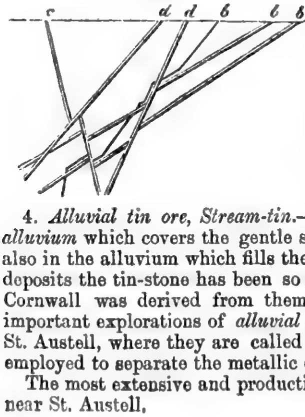
Stanniferous masses are much more frequent in the elvan (porphyry); of which the mine of Trewidden is a remarkable example. It was worked among flattened masses of elvan, separated by strata of killas, which dip to the east-north-east at a considerable angle. The tin ore occurred in small veins, varying in thickness from half an inch to 8 or 9 inches, which were irregular, and so much interrupted that it was difficult to determine either their direction or their inclination.

3. The large and proper metalliferous veins are not equally distributed over the surface of Cornwall and the adjoining part of Devonshire; but are grouped into three districts: namely, 1, In the south-west of Cornwall, beyond Truro; 2, In the neighbourhood of St. Austell; and 3, In the neighbourhood of Dartmoor in Devonshire.

The first group is by far the richest and the best explored. The great tin-veins are the most ancient metalliferous veins in Cornwall; yet they are not all of one formation, but belong to two or more different systems. Their direction is, however, nearly the same, but some of them dip towards the north, and others towards the south. It was formerly thought by the Cornish miners that tin occurred in the upper portions of the mineral lodes only, and mines were abandoned, when in sinking the miners came to the 'yellows'—*copper pyrites*, which were said 'to have cut out the tin.' Within the last few years, however, tin has been found at very great depths below the surface and beneath the copper. Dolcoath Mine is a very remarkable example of this. This mine was first worked as a tin mine for a very long period; then as a copper mine for half a century; and then, upon persevering in depth, the lode was found to become more and more rich in tin, which is now worked to great advantage. Other mines in the same locality have presented similar conditions.

At Trevaunance Mine the two systems of tin-veins are, both, intersected by the oldest of the copper-veins; indicating the prior existence of the tin-veins. In *fig.* 1981, *b* marks the first system of tin-veins; *c* the second; and *d* the east and west copper-veins. Some of these tin-veins, as at Poldice, have been traced over an extent of two miles; and they vary in thickness from a small fraction of an inch to several feet, the average width being from 2 to 4 feet; though this does not continue uniform for any length, as these veins are subject to continual narrowings and expansions. The gangue is quartz, chlorite, tourmaline, and sometimes decomposed granite and fluor-spar.

1981

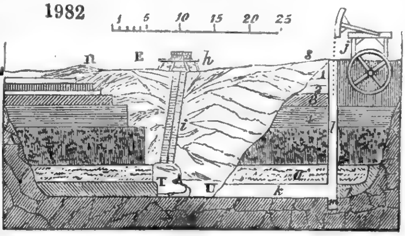


4. *Alluvial tin ore, Stream-tin.*—Peroxide of tin occurs disseminated both in the *alluvium* which covers the gentle slopes of the hills adjoining the rich tin mines, and also in the alluvium which fills the valleys that wind round their base; and in these deposits the tin-stone has been so abundant that for centuries the whole of the tin of Cornwall was derived from them; and it is still so to some extent. The most important explorations of *alluvial tin ore* are grouped in the environs of St. Just and St. Austell, where they are called *stream-works*, because water is the principal agent employed to separate the metallic oxide from the sand and gravel.

The most extensive and productive stream-works were formerly those of Pentewan, near St. Austell.

Fig. 1982 represents a vertical section of the Pentewan deposit, taken from the stream-work *Happy Union*, long since abandoned. A vast excavation, R, T, U, *s*, has been hollowed out in the open air, in quest of the alluvial tin ore T, which occurs here at an unusual depth, below the level of the strata R, *s*. Before getting at this deposit, several successive layers had to be sunk through, namely, 1, 2, 3, the gravel, containing in its middle a band of ochreous earth, 2, or ferruginous clay; 4, a black peat, perfectly combustible, of a coarse texture, composed of reeds and woody fibres, cemented into a mass by a fine loam; 5, coarse sea-sand, mingled with marine shells; 6, a blackish marine mud, filled with shells. Below these the deposit of tin-stone occurs, including fragments of various size, of clay-slate, flinty slate, quartz, iron ore, jasper; in a word, of all the rocks and gangues to be met with in the surrounding territory, with the exception of granite. Among these fragments there occurred, in rounded particles, a coarse quartzose sand, and the tin-stone, commonly in small grains and crystals. Beneath the bed T, is the clay-slate called *killas* (A, X, Y), which supports all the deposits of more recent formation.

1982



The system of mining employed in stream-works is very simple. The successive beds, whose thickness is shown in the figure, are visibly cut out into steps or platforms. By a level or gallery of efflux *k*, the waters flow into the bottom of the well *l*, *m*, which contains the drainage pumps; and these are put in action by a machine *j*, moved by a water-wheel. The extraction of the ore is effected by an inclined plane *i*, cut out of one of the sides of the excavation, at an angle of about 45 degrees. At the lower end of this sloping pathway there is a place of loading; and at its upper end *h*, a horse-gin, for alternately raising and lowering the two baskets of extraction on the pathway *i*.

Mine-tin—as distinguished from *Stream-tin*, the former being worked by the miner out of the lode—requires peculiar care in its mechanical preparation or dressing, on account of the presence of foreign metals, from which, as we have stated, stream-tin is free.

Tin ore, therefore, should be first of all pounded very fine in the stamp-mill, then subjected to reiterated washings, and afterwards calcined. The order of proceeding in Cornwall and other parts is fully described in the article DRESSING OF ORES. See also ROASTING, for a description of the roasting processes.

The tin ores of Cornwall and Devonshire are all smelted within the counties where they are mined: the vessels which bring the fuel from Wales, for smelting these ores, return to Swansea and Neath loaded with copper ores.

Australian Tin.—As far back as 1849 the Rev. W. B. Clarke, from the character of certain granites, predicted the occurrence of tin in New South Wales; and in 1853 he reported the actual discovery of tin ore near the Severn River. It was not, however, until recently that the tin ore of New South Wales and Queensland has been found in sufficient abundance to attract general attention. In New South Wales the tin-yielding district forms an elevated plateau of granitic rocks, associated with metamorphic slates and sandstones. The granite is, in places, traversed by veins of quartz, rich in tin-stone, and is capped by a deposit of tin-bearing detritus of variable thickness. The stanniferous district extends into the adjacent colony of Queensland, the ore having been traced over an area of about 550 square miles in the neighbourhood of the head-waters of the Severn River and its tributaries. The Queensland tin occurs partly in lodes associated with granitic rocks, and partly as stream-tin in beds of the rivers and in the alluvial flats on their banks.

From these new districts the following quantities have been obtained:—

In Victoria.—Tin has been found in the districts of Beechworth, Koetong, Upper Murray, Burrawa Creek, Yackandandah, Cudgewa Creek, La Trobe River, Corner Inlet, Chiltern, Mansfield, Foster, and Omea. In all cases the black tin has been obtained from alluvial deposits—generally termed 'black sand.' The quantity of tin produced in Victoria up to the end of 1873 has been as follows:—

	Tin Ore		Tin
	Tons	Cwts.	lbs.
Previously up to December 31, 1872	3,831	16	139,648
From January 1 to December 31, 1873	174	16	109,312
Total . . .	4,006	12	248,960

The Tin district of *New South Wales* from the commencement of the workings for tin unto the present time:—

	Ore Cwts.	Smelted Ingots Cwts.
1872	20,682	1,838
1873	78,300	20,595
1874	19,055 *for six months*	45,661 *for six months.*

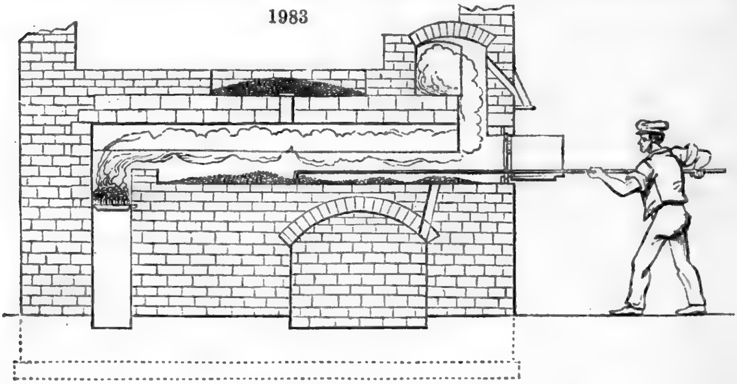
Queensland.

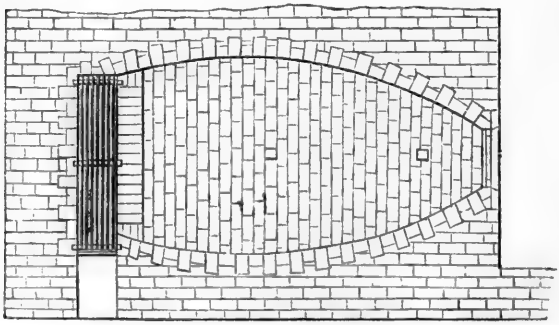
	Ore Tons	Ingots Tons
1873	1,440	280 to London
"	3,460	20 " Sydney
1874 to June	1,520	500 " London
"	1,760	16 " Sydney

Tasmania.—Tin ore has also been recently discovered at Mount Bischoff, in the north-western part of Tasmania. The ore is not only found as an alluvial deposit, but occurs in a porphyritic rock, resembling some of the Cornish elvans, and is in many places intimately associated with a gossany oxide of iron. It will be seen from the general statement of imports that a small quantity was sent from this colony. Large masses of tin have been found in the alluvial deposits, evidently derived from lodes; and we understand some lodes have been discovered.

Tin Dressing.—Most of the tin ores in Cornwall have to be roasted, or calcined, before they are fit for the smelting-house, although in some mines the admixture with other minerals is so trifling that this operation is considered unnecessary. The furnace (*figs.* 1983, 1984) in which the roasting is carried on, is about 10 feet long, 5 feet 6 inches wide in the middle, and 3 feet wide near the mouth. The fireplace, it will be observed, is situated at the back, the flames playing through the oven and ascending the chimney, which is above the furnace-door. The man is represented in *fig.* 1983, as stirring the ore with a long iron rake. The ore, before it is submitted to the action of the fire, is thoroughly dried in a circular pit, placed immediately above the oven, into which

1983

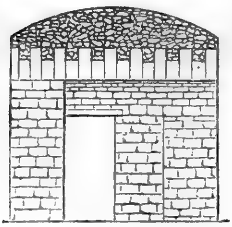




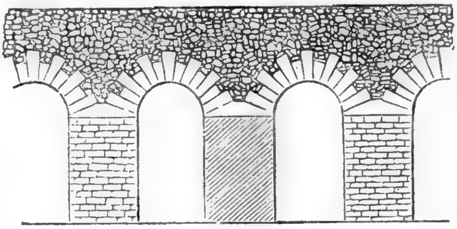
1984

it is let down through the opening, when it is considered to be ready for calcining. Beneath the oven and connected with it by an opening through which the ore when sufficiently roasted is made to pass, is an arched opening about 4 feet wide, termed the 'wrinkle.' Here the ore is collected, whilst another charge is being placed in the furnace. About 7 cwts. or 8 cwts. of ore is the quantity usually roasted at one time. Whilst undergoing this operation, dense fumes of arsenic and sulphur escape with the smoke from the fire, and pass through large flues, divided into several chambers (*figs.* 1985 to 1987) where the former is collected. The flue is often 70 yards long, and the greatest deposit of arsenic takes place at about 15 yards from the oven or furnace. Instead of being at once completely roasted, the 'whits' from the stamps are sometimes first 'rag' (or partially) burnt, for about six or eight hours. The object of this partial burning is to save time and expense, nearly three-fourths of it being thrown away after dressing it from the first burning.

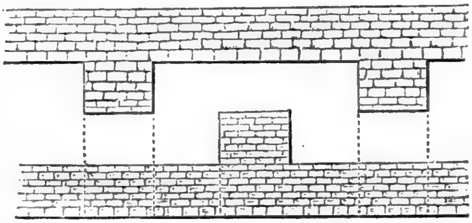
1985



1986



1987



The machine called originally 'Brunton's Patent Calciner' (*fig.* 1988), for calcining tin ore, is gradually coming into use in Cornwall, and is adopted in many of the larger mines. Its operation may be thus briefly described :—A revolving circular table, usually 8 feet or 10 feet in diameter, turned by a water-wheel, receives through the hopper the tin-stuff to be roasted or calcined. The frame of the table is made of cast iron, with bands, or rings, of wrought iron, on which rests the fire-bricks composing the surface of the table. The flames from each of the two fireplaces pass over the ore as it lies on the table, which slowly revolves at the rate of about once in every quarter of an hour. In the top of the dome, over the table, are fixed three cast-iron frames, called the 'spider,' from which depend numerous iron coulters, or teeth, which stir up the tin-stuff, as it is carried round under them. The coulters on one of the arms of the 'spider' are fixed obliquely, so as to turn the ore downwards from one to the other—the last one at the circumference of the table, projecting the ore (by this time fully calcined) over the edge, into one of the two 'wrinkles' beneath. A simple apparatus called the 'butterfly,' moved by a handle outside the building, diverts the stream of roasted tin-stuff, as it falls from the table, either into one or the other as may be required. Unlike the operation of roasting in the oven previously described, the calciner requires little or no attention ; the only care requisite being to see that the hopper is fully supplied, and the roasted ore removed when necessary from the wrinkles.

For this description of the burning-house and of the calciner, we are indebted to Mr. James Henderson's communication to the Institution of Civil Engineers.

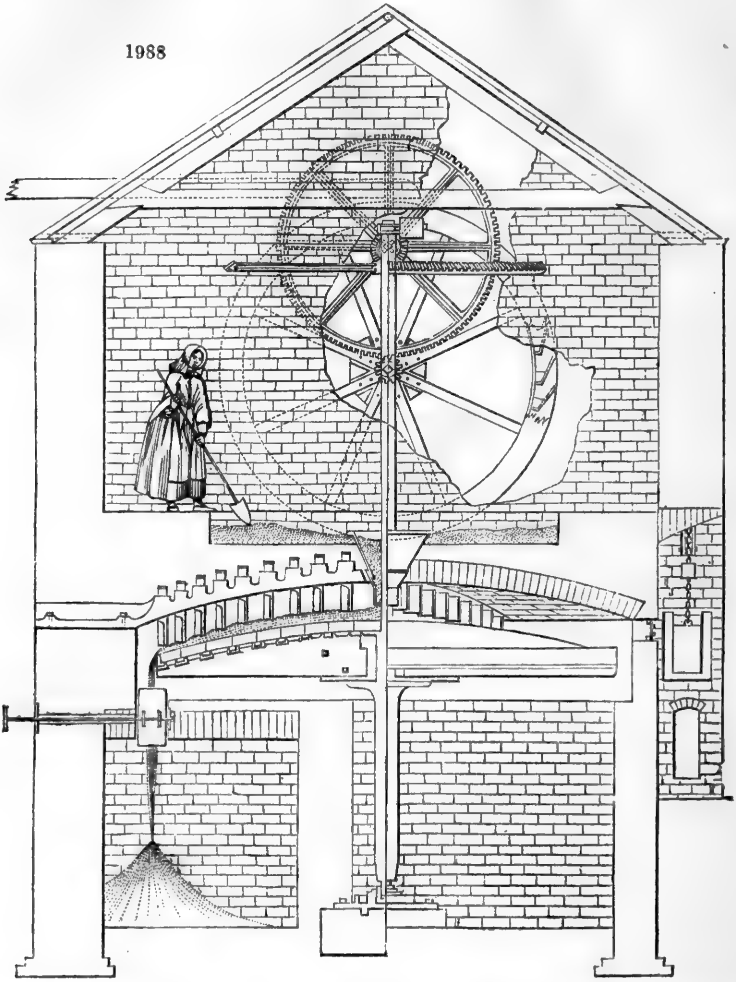
We have been favoured with the following notes on the action of Brunton's calciners, employed at Fabrica la Constanto, Spain, which are of great value, as are also the additional suggestions.

Diameter of revolving bed, 14 feet.

Revolution of bed per hour from 3 to 4, or about 1 foot of the circumference per minute.

Ores introduced by hopper, at the rate of 1 quintal to every revolution of table.
Quantity of ore calcined per day of 10 hours, 30 to 35 quintals.
Salt consumed, generally six per cent. of weight of ore.
Fuel consumed per 10 hours, 1,200 to 1,400 lbs. of pine-wood.
Power employed to revolve table, half horse.

1988



Remarks.—The furnace is charged with ore and salt by means of iron hoppers placed immediately over the centre of each of the hearths. For the supply of each hopper, a heap of about 14 quintals of ore, with 5 or 6 per cent. of salt, is prepared from time to time upon a small platform on the top of the furnaces, and a few shovelsful thrown in occasionally as required, taking care, however, always to have enough ore in the hopper to prevent the ascension of acid vapours, &c., from the furnace. The time the mineral remains in the furnace, and the quantity calcined per hour, must depend on the rapidity of motion of the revolving hearth, and the angle at which the iron stirrers are fixed.

The average amount passed through each furnace in 24 hours is about 84 quintals or 3½ quintals per hour. For every revolution of the bed, nearly 1 quintal is discharged from the furnace.

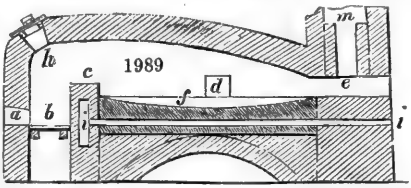
The smelting of tin ores has been effected by two different methods :—

In the first a mixture of the ore with anthracite was exposed to heat on the hearth of a reverberatory furnace fired with coal.

In the second, the tin ore was fused in a blast-furnace, called a blowing-house, supplied with wood-charcoal. This method is not now practised in England.

In the *smelting-houses*, where the tin is worked in reverberatories, two kinds of furnaces are employed; the reduction and the refining furnaces.

Figs. 1989 and 1990 represent the furnaces for smelting tin at Truro, in Cornwall: the former being a longitudinal section, the latter a ground plan. *a* is the fire-door, through which pitcoal is laid upon the grate *b*; *c* is the fire-bridge; *d*, the door for introducing the ore; *e*, the door through which the ore is worked upon the hearth *f*; *g*, the stoke-hole; *h*, an aperture in the vault or roof, which is opened at the discharge of the waste schlich, to secure the free escape of the fumes up the chimney; *i*, *i*, air-channels, for admitting cold air under the fire-bridge and the sole of the hearth, with the view of protecting them from injury by the intensity of the heat above. *k*, *k*, are basins into which the melted tin is drawn off; *l*, the flue; *m*, the chimney, from 35 to 50 feet high. The roasted and washed schlich is mixed with small coal or culm, along with a little slaked lime, or fluor-spar, as a flux; each charge of ore amounts to from 15 to 24 cwts., and contains from 60 to 70 per cent. of metal.


1989

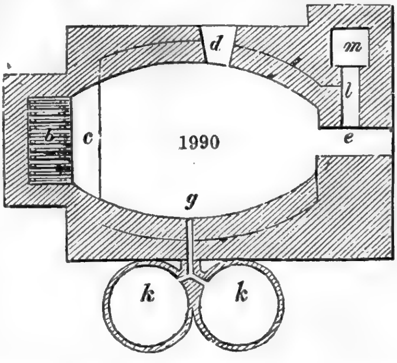
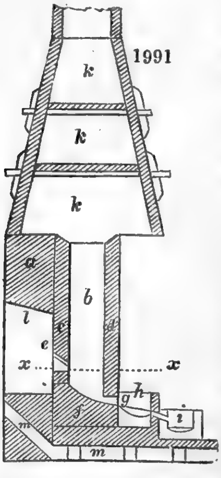

1990

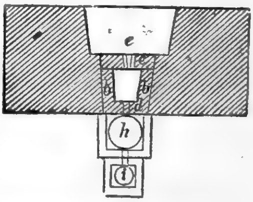
Fig. 1991 represents in a vertical section through the tuyère, and *fig.* 1992, in a horizontal section, in the dotted line *x*, *x*, of *fig.* 1991, the furnace employed for smelting tin at the Erzegebirge mines in Saxony. *a*, are the furnace-pillars, of gneiss; *b*, *b*, are shrouding or casing walls; *c*, the tuyère wall; *d*, front wall, both of granite; as also the tuyère *e*. *f*, the sole stone, of granite, hewn out basin-shaped; *g*, the *eye*, through which the tin and slag are drawn off into the fore-hearth *h*; *i*, the stoke-hearth; *k*, *k*, the light ash-chambers; *l*, the arch of the tuyère; *m*, *m*, the common flue, which is placed under the furnace and the hearths, and has its outlet under the vault of the tuyère.


1991

In the smelting-furnaces at Geyer the following dimensions are preferred: length of the tuyère wall, 11 inches; of the breast wall, 11 inches; depth of the furnace 17 inches. High chimney-stalks are advantageous where a great quantity of ores is to be reduced, but not otherwise.

The *refining furnaces* are similar to those which serve for reducing the ore; only, instead of a basin of reception, they have a refining basin placed alongside into which the tin is run. This basin is about 4 feet in diameter, and 32 inches deep; it consists of an iron pan, placed over a grate, in which a fire may be kindled. Above this pan there is a turning gib, by means of which a billet of wood may be thrust down into the bath of metal, and kept there by wheeling the gibbet over it, lowering a rod, and fixing it in that position.

1992



Formerly in Cornwall nearly all the tin was smelted in blast-furnaces; these works were called *blowing-houses.* The smelting-furnaces were 6 feet high from the bottom of the crucible (concave hearth) to the throat, which is placed at the origin of a long and narrow chimney, interrupted by a chamber, where the metallic dust carried off by the blast was deposited. This chamber was not placed vertically over the furnace; but the lower portion of the chimney had an oblique direction from it. The furnace was lined with an upright cylinder of cast iron, coated internally with loam, with an opening in it for the blast. This opening, which corresponds to the lateral face opposite to the charging side, receives a tuyère, in which the nozzles of two cylinder single bellows, driven by a water-wheel, were planted. The tuyère opens at a small height above the sole of the furnace. On a level with the sole, the iron cylinder presents a slope, below which was the hemispherical basin of reception, set partly beneath the interior space of the furnace, and partly without. Near the corner of the building there was a second basin of reception, larger than the first, which could discharge itself into the former, by a sloping gutter. Near this basin there was another, for the refining operation. These were all made either of brick or cast iron. Such blast-furnaces are now entirely superseded in this country by the reverberatory furnace.

The quality of the average ground tin ore prepared for smelting is such that 20 parts of it yield from 12½ to 13 of metallic tin (62½ to 65 per cent.) The treatment consists of two operations, *smelting* and *refining*.

First operation; deoxidisation of the ore, and fusion of the tin.—Before throwing the ore into the smelting furnace, it is mixed with from one-fifth to one-eighth of its weight of *blind coal*, in powder, called *culm*; and a little slaked lime is sometimes added, to render the ore more fusible. These matters are carefully blended, and damped with water to render the charging easier, and to prevent the draught from sweeping any of it away at the commencement. From 20 to 25 cwts. are introduced at a charge; and the doors are immediately closed and luted, while the heat is progressively raised. Were the fire too strong at first, the tin oxide would unite with the quartz of the gangue, and form an enamel. The heat is applied for 6 or 8 hours, during which the doors are not opened; of course the materials are not stirred. By this time the reduction is in general finished; the door of the furnace is removed, and the melted mass is worked up to complete the separation of the tin from the scoriæ, and to ascertain if the operation be in sufficient forwardness. When the reduction seems to be finished, the scoriæ are taken out at the same door, with an iron rake, and divided into three sorts: those of the first class A, which constitute at least three-fourths of the whole, are as poor as possible, and may be thrown away; the scoriæ of the second class B, which contain some small grains of tin, are sent to the stamps; those of the third class C, which are last removed from the surface of the bath of tin, are set apart, and re-smelted, as containing a considerable quantity of metal in the form of globules. These scoriæ are in small quantity. The stamp-slag contains fully 5 per cent. of metallic tin.

As soon as the scoriæ are cleared away, the channel is opened which leads to the basin of reception, into which the tin consequently flows out. Here it is left for some time, that the scoriæ which may be still mixed with the metal may separate, in virtue of the difference of their specific gravities. When the tin has sufficiently settled, it is lifted out with ladles, and poured into cast-iron moulds, in each of which a bit of wood is fixed, to form a hole in the ingot, for the purpose of drawing i out when it becomes cold.

Refining of Tin.—The object of this operation is to separate from the tin, as completely as possible, the metals reduced and alloyed along with it. These are, principally, iron, copper, arsenic, and tungsten; to which are joined, in small quantities, some sulphides and arsenides that have escaped decomposition, a little unreduced oxide of tin, and also some earthy matters which have not passed off with the scoriæ.

Liquation.—The refining of tin consists of two operations; the first being a liquation, which, in the interior, is effected in a reverberatory furnace similar to that employed in smelting the ore (*figs.* 1989, 1990). The blocks being arranged on the hearth of the furnace, near the bridge, are moderately heated; the tin melts, and flows away into the refining-basin; but, after a certain time, the blocks cease to afford tin, and leave on the hearth a residuum, consisting of a very ferruginous alloy.

Fresh tin-blocks are now arranged on the remains of the first; and thus the liquation is continued till the refining-basin be sufficiently full, when it contains about 5 tons. The residuums are set aside, to be treated as shall be presently pointed out.

Refining proper.—Now begins the second part of the process. Into the tin-bath billets of green wood are plunged, by the aid of the gibbet above described. The disengagement of gas from the green wood produces a constant ebullition in the tin; bringing up to its surface a species of froth, and causing the impurest and densest parts to fall to the bottom. That froth, composed almost wholly of the oxides of tin and foreign metals, is successively skimmed off, and thrown back into the furnace. When it is judged that the tin has boiled long enough, the green wood is lifted out, and the bath is allowed to settle. It separates into different zones, the upper being the purest; those of the middle are charged with a little of the foreign metals; and the lower are much contaminated with them. When the tin begins to cool, and when a more complete separation of its different qualities cannot be looked for, it is lifted out in ladles, and poured into cast-iron moulds. It is obvious that the order in which the successive blocks are obtained is that of their purity; those formed from the bottom of the basin being usually so impure that they must be subjected anew to the refining process, as if they had been directly smelted from the ore.

The refining operation takes five or six hours; namely, an hour to fill the basin, three hours to boil the tin with the green wood, and from one to two hours for the subsidence.

Sometimes a simpler operation, called *tossing*, is substituted for the above artificial ebullition. To effect it a workman lifts some tin in a ladle, and lets it fall back into the boiler from a considerable height, so as to agitate the whole mass. He continues this manipulation for a certain time; after which, he skims with care the surface of the bath. The tin is afterwards poured into moulds, unless it be still impure. In this case the separation of the metals is completed by keeping the tin in a fused state in the boiler for a certain period, without agitation; whereby the upper portion of the bath (at least one-half) is pure enough for the market.

The moulds into which the tin-blocks are cast are usually made of granite. Their capacity is such, that each block shall weigh a little more than 3 cwts. This metal is called 'block tin.' The law requires them to be stamped or *coined* by public officers, before being exposed to sale. The purest block tin is called 'refined tin.'

The treatment just detailed gives rise to two stanniferous residuums, which have to be smelted again. These are—

1. The scoriæ B and C, which contain some granulated particles of tin.
2. The dross found on the bottom of the reverberatory furnace, after re-melting the tin to refine it.

The scoriæ C are smelted without any preparation; but those marked B are stamped in the mill, and washed, to concentrate the tin-grains; and from this rich mixture, called *prillion*, smelted by itself a tin is procured of very inferior quality. This may be readily imagined, since the metal which forms these granulations is what, being less fusible than the pure tin, solidified quickly, and could not flow off into the metallic bath.

Whenever all the tin-blocks have thoroughly undergone the process of liquation, the fire is increased, to melt the less fusible residuary alloy of tin with iron and some other metals, and this is run out into a small basin, totally distinct from the refining-basin. After this alloy has reposed for some time, the upper portion is lifted out into block-moulds, as impure tin, which needs to be refined anew. On the bottom and sides of the basin there is deposited a white, brittle alloy, with a crystalline fracture, which contains so great a proportion of foreign metals that little use can be made of it. About 3½ tons of coal are consumed in producing 2 of tin.

Summary of Produce of Tin in Cornwall and Devon for each of the ten years ending 1873.

Year	No. of mines	Tin ore		Metallic tin	
		Quantity	Value	Quantity	Value
		Tons	£	Tons	£
1864	174	13,985	881,031	9,295	995,029
1865	156	14,122	782,284	9,038	873,659
1866	145	13,785	667,999	8,822	781,849
1867	117	11,066	549,375	7,296	670,228
1868	109	11,584	641,137	7,703	756,494
1869	117	13,883	889,378	9,356	1,138,488
1870	147	15,234	1,002,357	10,200	1,299,505
1871	145	16,898	1,068,733	11,320	1,556,557
1872	162	12,300	1,065,658	8,241	1,258,812
1873	215	14,885	1,056,835	9,972	1,329,766

Production of the Dutch Tin Mines for the last 19 *years.*

Years	Banca[1]		Billiton, estimated	
	Slabs	Tons	Slabs	Tons
1855	128,256 =	4,233	2,734 =	97
1856	201,317	6,643	6,714	238
1857	149,336	4,928	3,674	130
1858	192,950	6,367	9,014	320
1859	181,968	6,005	4,620	164
1860	165,620	5,465	8,000	284
1861	173,008	5,709	13,018	462
1862	141,770	4,678	10,182	361
1863	191,963	6,334	20,636	732
1864	161,916	5,343	22,380	794
1865	138,012	4,554	30,000	1,065
1866	158,626	5,234	33,000	1,171
1867	140,570	4,639	65,940	2,341
1868	120,000	3,960	60,600	2,151
1869	135,868	4,483	68,291	2,424
1870	146,000	4,672	89,283	2,858
1871	134,906	4,320	99,700	3,100
1872	136,906	4,325	108,000	3,456
1873	140,000	4,480	102,000	3,264

Imports of Tin in the year 1873.

Countries from which imported	Tin ore	Tin, blocks, ingots, bars, and regulus
	Tons	Tons
Holland	1	1,770
France	30	115
Portugal	12	...
Spain	7	...
Straits Settlements	1	4,812
China	...	25
Victoria	297	58
New South Wales	3,114	331
Queensland	1,302	103
Tasmania	13	...
United States of America: On the Atlantic	...	72
Peru	671	387
Chili	157	114
Other parts	7	4
Total Imports	5,612	7,791

To test the quality of tin, dissolve a certain weight of it with heat in hydrochloric acid; should it contain arsenic, brown-black flocks will be separated during the solution, and arseniuretted hydrogen gas will be disengaged, which, on being burned at a jet, will deposit the usual grey film of metallic arsenic upon a white saucer held a little way above the flame. Other metals present in the tin are to be sought for by treating the above solution with nitric acid of spec. grav. 1·16, first in the cold, and at last with heat and a small excess of acid. When the action is over, the supernatant liquid is to be decanted off the peroxidised tin, which is to be washed with very dilute nitric acid, and both liquors are to be evaporated to dissipate the acid excess. If, on the addition of water to the concentrated liquor, a white powder falls, it is a proof that the tin contains bismuth; if, on adding sulphate of ammonia, a white precipitate appears, the tin contains lead; water of ammonia added to supersaturation will occasion reddish-brown flocks, if iron is present; and on evaporating the supernatant liquid to dryness, the copper will be obtained.

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[1] 1,000 Banca slabs weigh about 22 tons; the average weight of 1,000 slabs Straits tin being from 35 to 40 tons. The weight of the Billiton slabs is the same as the Banca.

Tin in Ingots, blocks, bars, slabs or regulus, *Imported* in 1874, 184,377 cwts.; value 904,488*l.*

Tin unwrought *Exported* in 1874, 155,068 cwts.; value 813,305*l.*

For the purification of tin from tungsten, see TUNGSTEN.

The uses of tin are very numerous. Combined with copper, in different proportions, it forms Bronze, and a series of other useful alloys; for an account of which, see COPPER. With iron, it forms Tin-plate; with lead, it constitutes Pewter, and Solder of various kinds. (See LEAD.) Tin-foil coated with quicksilver makes the reflecting surface of glass mirrors. (See GLASS.) Nitrate of tin affords the basis of the scarlet dye on wool, and of many bright colours to the calico-printer and the cotton-dyer. (See SCARLET and TIN-MORDANTS.) A compound of tin with gold gives the fine crimson and purple colours to stained glass and artificial gems. (See PURPLE OF CASSIUS.) Enamel is made by fusing oxide of tin with the materials of flint glass. This oxide is also an ingredient in the white and yellow glazes of pottery-ware. See PUTTY POWDER.

TIN ASSAYING. The ore of tin submitted to assay is Cassiterite, peroxide of tin or black tin. When the ore is poor it must be submitted to a washing, vanning, or other concentration process, to separate the peroxide of tin from vein-stuff before submitting it to the assay. If the ore is associated with iron pyrites, copper pyrites, or other foreign metalliferous matters, it must be calcined or treated with acids, before submitting it to the final washing process. The assays are made by the dry method.

a. Cornish method. This process is conducted in black-lead crucibles in an air-furnace similar to that described in COPPER (*Fig.* 533). Two ounces (960 grs.) of the ore are mixed with about one-fifth of its weight of culm or anthracite powder, or charcoal, and heated for about twenty minutes at a high temperature; the reduced metal is now poured out into a long flat ingot-mould. The slaggy residue is then scraped out from the pot, and any shots of metal separated by pounding and washing, and the total weight of metal ascertained. A small quantity of borax or fluor-spar is added when necessary to render the slag fluid. The assay may also be made in earthen crucibles.

b. By Fusion with Cyanide of Potassium. This process is conducted in earthen or porcelain crucibles: 100 grs. of the black tin is a convenient quantity to operate on. The ore is mixed with from four to six times its weight of cyanide of potassium, and the crucible and its contents exposed to a low red heat for about 20 minutes. The contents are poured out into the iron mould (*fig.* 534, see COPPER), and when cold the button of tin is detached from the slag, cleaned and weighed.

TINCAL. The Oriental name for crude borax. Under this name considerable quantities are brought from the East Indies. But the largest quantities are obtained from the lagoons near Monte Cerbole in Tuscany. Recently, tincal of a very fine quality has been discovered in California. A lake in Colorado Territory contained so much of the bi-borate of soda that it was found crystallised out around the edges, but was soon exhausted. See BORAX.

TINCTORIAL MATTER. The colouring-matter employed in dyeing. See DYEING; MADDER; TURKEY RED, &c.

TINCTURE is a title used by apothecaries to designate alcohol, in a somewhat dilute state, impregnated with the active principles of either vegetable or animal substances.

TINDER ORE. (*Zundererz*, Ger.) An impure arsenical sulphide of antimony. It is found at Andreasberg in the Hartz, in soft flexible flakes resembling tinder, of a dirty reddish colour and with little lustre.

TINE, *in metallurgy*, a modification of the *Trompe* adopted by the French.

TIN GLANCE is an old name of bismuth. See BISMUTH.

TIN-MORDANTS for dyeing scarlet. See MORDANT.

Mordant A, as commonly made by the dyers, is composed of 3 parts of nitric acid, 1 part of common salt or of sal-ammoniac, and 1 of granulated tin. This preparation is very uncertain.

Mordant B. Pour into a glass globe with a long neck, 3 parts of pure nitric acid at 30° B., and 1 part of muriatic acid at 17°; shake the globe gently, avoiding the corrosive vapours, and put a loose stopper in its mouth. Throw into this nitro-muriatic acid, one-eighth of its weight of pure tin, in small bits at a time. When the solution is complete, and settled, decant it into bottles, and close them with ground stoppers. It should be diluted only when about to be used.

Mordant C, by Dambourney.—In 2 drams (Fr., 144 grs.), of pure muriatic acid, dissolve 18 grains of Malacca tin. This is reckoned a good mordant for brightening or fixing the colour of peachwood.

Mordant D, by Hellot.—Take 8 ounces of nitric acid, diluted with as much water; dissolve in it half an ounce of sal-ammoniac, and 2 drams of nitre. In this acid solution dissolve 1 ounce of granulated tin of Cornwall, observing not to put in a fresh piece till the preceding be dissolved.

Mordant E, by Scheffer.—Dissolve 1 part of tin in 4 of nitro-muriatic acid, prepared with nitric acid diluted with its own weight of water, and one thirty-secondth of sal-ammoniac.

Mordant F, by Poerner.—Mix 1 pound of nitric acid with 1 pound of water, and dissolve it in an ounce and a half of sal-ammoniac. Stir it well, and add, by very slow degrees, 2 ounces of tin turned into thin ribbons upon the lathe.

Mordant F, by Berthollet.—Dissolve in nitric acid of 30° B., one-eighth of its weight of sal-ammoniac, then add by degrees one-eighth of its weight of tin, and dilute the solution with one-fourth of its weight of water.

Mordant K, by Dambourney.—In 1 dram (72 grs.) of muriatic acid at 17°, one of nitric acid at 30°, and 18 grains of water, dissolve slowly, and with some heat, 18 grains of fine Malacca tin.

Mordant L, is the birch-bark prescribed by Dambourney. This bark, dried, and ground, is said to be a very valuable substance for fixing the otherwise fugitive colours produced by woods, roots, archil, &c.

TIN-PLATES. The art of coating copper with tin seems to have been known at an early period. Pliny refers to this, and from his description it is probable the vessels to be covered were dipped into melted tin, and the '*vasa stannea*' of the Romans were copper vessels covered with tin. The difficulty of coating iron with tin was, however, much greater; and the process of hammering the iron into sheets sufficiently thin, and cleaning the surface, which latter work had often to be done by filing, were serious hindrances to the extensive use of the invention.

The art of tinning iron appears to have been first practised in Bohemia, and about the year 1620 to have been introduced into Saxony.

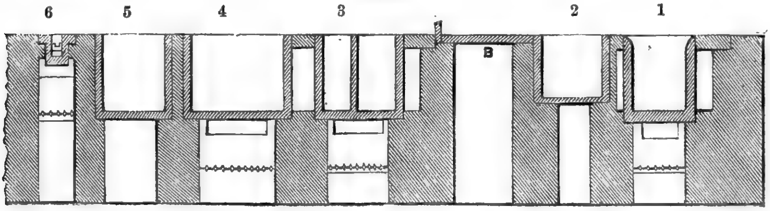
Beckmann states that, 'in the year 1670, a company sent to Saxony, at their expense, an ingenious man named Andrew Yarrenton, in order to learn the process of tinning. Having acquired the necessary knowledge, he returned to England with some German workmen, and manufactured tin-plate which met with general approbation. Before the company could carry on business on an extensive scale, a man of some distinction, having made himself acquainted with Yarrenton's process, obtained a patent for his art, and the first undertakers were obliged to give up their enterprise, which had cost them a great deal of money, and yet no use whatever was made of the patent which had been obtained.' About the year 1720 works for the manufacture of tin-plates were established at Pontypool, and these seem to be the earliest of such works in England which were permanently successful.

In 1728, John Payne invented a process for rolling iron. This seems to have at once led to the use of the flat or sheet rolls for the manufacture of iron for tin-plates; but it is very remarkable that no further progress was made in this discovery of rolling iron until 1783, when Henry Cort invented the grooved rolls. This discovery was not appreciated for some years. Mr. Reynolds, of Ketley, erected Cort's rolls in 1785. In 1790 Henry Cort was engaged by Mr. Richard Crawshay to erect the mills at Cyfarthfa, and, soon after, this important improvement in the iron manufacture was generally adopted. The writer proposes to give in this paper a short *résumé*, first, of the process for cleaning and tinning the iron-plate, and after, of the methods of preparing the iron for this purpose.

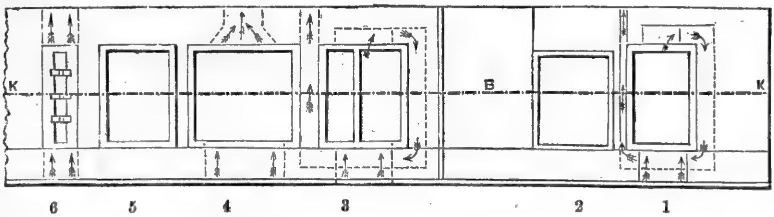
The affinity of iron for tin is much greater than is generally supposed. The point at which the metals cohere is no doubt an *actual alloy;* and advantage is taken of this by the manufacturers of articles for domestic use, made in iron—as bridle-bits, common stirrups, small nails, &c. When the iron, whether wrought or cast, *is perfectly clean and free from rust*, and brought in contact with melted tin, at a high temperature, an alloy seems to be at once formed, protecting the iron from oxidisation whilst the tin lasts. Many plans are used for tinning iron articles, of small size, by the manufacturers. One of the common methods of the manufacturers of bridle-bits and small ware, in South Staffordshire, is to clean the surface of the articles to be tinned, by steeping them for sufficient time in a mixture of sulphuric and hydrochloric acids, diluted with water, then washing them well with water, but taking great care they do not rust, at once placing them in a partially closed stoneware vessel (such as a common bottle), which contains a mixture of tin and sal-ammoniac. This vessel is then placed on a smith's hearth, duly heated, and frequently agitated to secure the complete distribution of the tin over the iron. The articles, when thus tinned, are thrown into water to wash away all remains of the sal-ammoniac; and lastly, cleaned in hot bran, or sawdust, to improve the appearance for sale.

The plans of cleaning and preparing the iron for tinning have undergone many changes in the past century. About 1720 the plan of cleaning was to scour the plates with sand and water, and file off the rough parts, then cover with resin, and dip them in the melted tin. About 1747 the plates were, after being cold-rolled, soaked for a week in the lees of bran, which had been allowed to stand in water about ten days, to become, by fermentation sufficiently acid, and then scoured with sand and water. In 1760 the plates were pickled in dilute hydrochloric acid before annealing, and cleaned with dilute sulphuric acid after being taken out of the bran lees. An improvement of great importance in this process was made about 1745; the inventor seems to have been Mr. Mosely, who carried on tin-plate works in South Staffordshire. This invention was the use of the grease-pot, and in this department little, if any, improvement has since been made. The plan was introduced into South Wales in 1747 by Mr. John Jenkins, and his descendants are still amongst the principal manufacturers in the trade. The process of cleaning and tinning at some of the best works now is as follows:—When the sheet iron leaves the plate-mill, and after separating the plates, and sprinkling between each plate a little sawdust, the effect of which is to keep them separate, they are then immersed, or as technically termed 'pickled,' in dilute sulphuric acid, and after this placed in the annealing-pot, and left in the furnace about 24 hours; on coming out, the plates are passed through the cold rolls; after passing the cold rolls, the plates seem to have too much the character of steel, and are not sufficiently ductile: to remedy this they are again annealed at a low heat, washed in dilute sulphuric acid, to remove any scale of oxide of iron, and scoured with sand and water; the plates in this state require to be perfectly clean and bright, and may be left for months immersed in pure water without rust or injury; but a few minutes' exposure to the air rusts them. With great care to have them perfectly clean, they are taken to the stow, *fig.* 1993, being a section through the line K K of the plan *fig.* 1994. Taken from right to left, 1 represents the tinman's pan; 2, the tin-pot; 3, the washing or dipping pot; 4, the grease-pot; 5, the cold pot; 6, the list pot.

1993

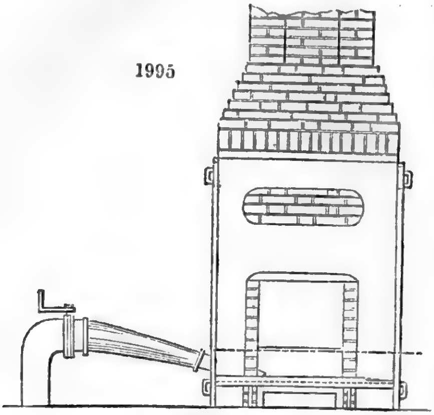


1994



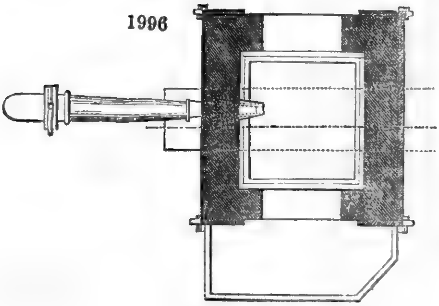
The tinman's pan is full of melted grease: in this the plates are immersed, and left there until all aqueous moisture upon them is evaporated, and they are completely covered with the grease; from this they are taken to the tin-pot, and there plunged into a bath of melted tin, which is covered with grease; but as in this first dipping the alloy is imperfect, and the surface not uniformly covered, the plates are removed to the dipping or wash pot; this contains a bath of melted tin covered with grease, and is divided into two compartments. In the larger compartment the plates are plunged, and left sufficiently long to make the alloy complete, and to separate any superfluous tin which may have adhered to the surface; the workman takes the plate and places it on the table marked B on the plan and wipes it on both sides with a brush of hemp; then to take away the marks of the brush, and give a polish to the surface, he dips it in the second compartment of the washing pot. This last always contains the purest tin, and as it becomes alloyed with the iron it is removed on to the first compartment, and after to the tin-pot. The plate is now removed to the grease-pot (No. 4); this is filled with melted grease, and requires very skilful management as to the temperature it is to be kept at. The true object is to allow any superfluous tin to run off, and to prevent the alloy on the surface of the iron plate cooling quicker than the iron. If this were neglected the face of the plate would be cracked. The plate is removed to the cold pot (No. 5): this is filled with tallow, heated to a comparatively low temperature. The use of the grease-pots, Nos. 4 and 5 is the process adopted in practice for annealing the alloyed plates. The list pot (No. 6) is used for the purpose of removing a small wire of tin, which adheres to the lower edge of the plate in all the foregoing processes. It is a small cast-iron bath, kept at a sufficiently high temperature, and covered with tin about one-fourth of an inch deep. In this the edges of the plates are dipped, and left until the wire of tin is melted, and then detached by a quick blow on the plate with a stick. The plates are now carefully cleaned with bran to free them from grease. Lastly, they are taken to the sorting-room, where every plate is separately examined and classed, and packed in boxes for market as hereafter described.

1995



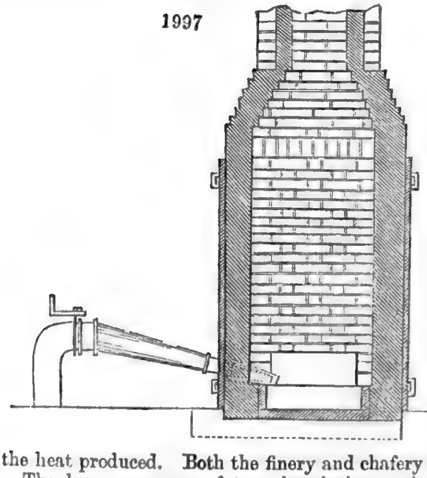
The tests of quality for tin-plates are—ductility, strength, and colour. To obtain these, the iron must be of the best quality, and the manufacture must be conducted with proportionate skill. This necessity will explain to some extent the cause why nearly all the improvements in working iron during the past century have been either originated or first adopted by the tin-plate makers, and a sketch of the processes used at different times, in working iron for tin-plates, will be, in fact, a history of the trade.

1996



The process of preparing the best or charcoal iron seems to have undergone but little change from 1720 to 1807. The finery, the chafery, and the hammer, were the modes of bringing the iron from the pig to the state of finished bars. The finery was of the exact form of the *figs.* 1995, 1996, 1997, but less in size than those now used. The chafery or hollow fire was, in fact, the same as the present smiths' forge fire, but on a larger scale; and the '*hollow*,' or chamber, in which the bloom was heated, was made by coking the coal in the centre with the blast, and taking care not to disturb the mass of coal above, which was used to reverberate the heat produced. Both the finery and chafery were worked by blast.

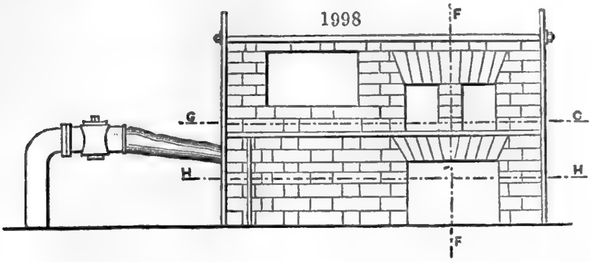
1997



The hammers were of two descriptions: the forge hammer, a heavy mass for shaping the blooms, and the tilt hammer, much lighter and driven quicker, for shaping the bars.

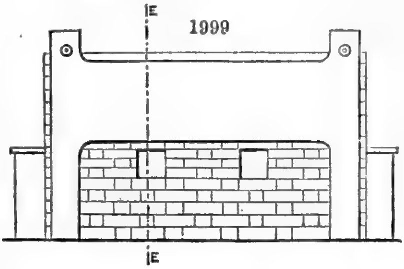
The charge for the finery was about 1½ cwt. of pig-iron; this, under the first process, was reduced to 1¼ cwt. It was, when ready, put under the forge hammer, and shaped into a 'bloom,' about 2 feet long and 5 inches thick; this was then heated in the chafery, and under the tilt hammer drawn out to a 'bar,' 3 to 4 inches wide, and half an inch thick.

1998



The manufacture up to this point was formerly carried on by the iron-masters, and the iron in this state was sold under the name of 'tin bars' to the plate-makers. The average price for these bars, from 1780 to 1810, was 21*l.* per ton. The sheet and cold rolls were then in use nearly as at the present time.

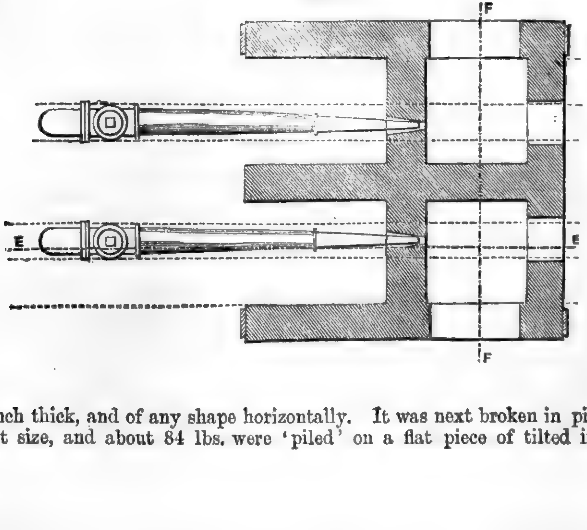
1999



In 1807, Mr. Watkin George, whose position had been established as one of the first engineers of his time, by the erection of the great water-wheel and works at Cyfarthfa, removed to Pontypool, and undertook the remodelling of the old works there. He clearly saw that the secret of the manufacture was to produce the largest possible quantity with least possible machinery and labour. His inventions, to this end, worked a complete change in the trade. His plans were: to first reduce the pig-iron in a finery under coke, and then bring this 'refiners' metal' (so termed) into the charcoal finery. The charcoal finery was built as shown in *figs.* 1995, 1996, and 1997: *fig.* 1995 being a front elevation, *fig.* 1996 a horizontal, and *fig.* 1997 a vertical section.

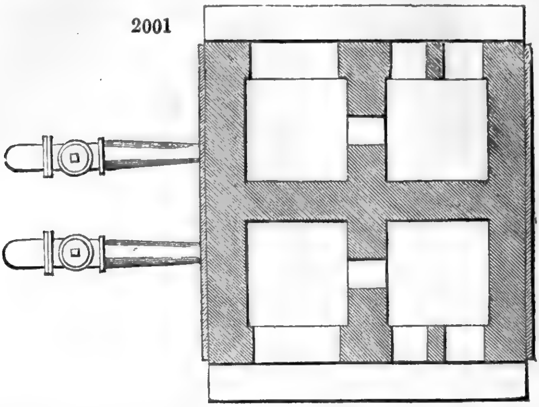
A charge of 3 cwts. of iron was used in this, and as it became malleable it was reduced under the hammer to what he termed a 'stamp:' this was a piece of iron about 1 inch thick, and of any shape horizontally. It was next broken in pieces of a convenient size, and about 84 lbs. were 'piled' on a flat piece of tilted iron, with

2000

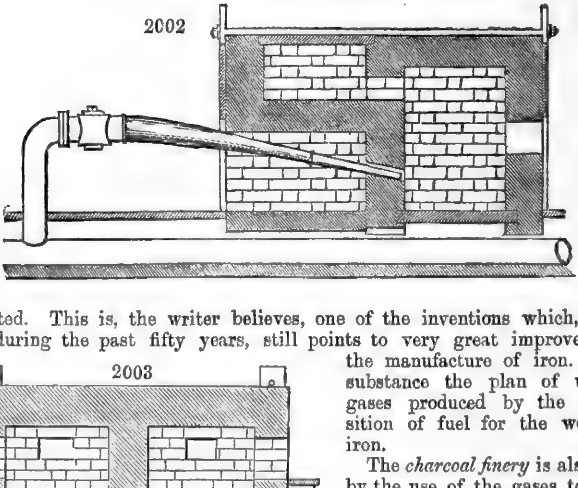


a handle about 4 feet long. This rough shovel, or holder, was called the 'portal,' or the 'staff.' To re-heat this 'pile' in the chafery would be a work of great cost and difficulty, and the brick hollow fire (as shown in *figs.* 1998 to 2003; *figs.* 1998 and 1999 being elevations, and *figs.* 2000, 2001, 2002, and 2003 sections) was invented. This is, the writer believes, one of the inventions which, although in work during the past fifty years, still points to very great improvements in the manufacture of iron. It is in substance the plan of using the gases produced by the decomposition of fuel for the working of iron.

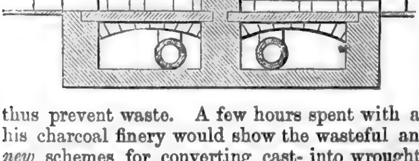
2001



2002



2003



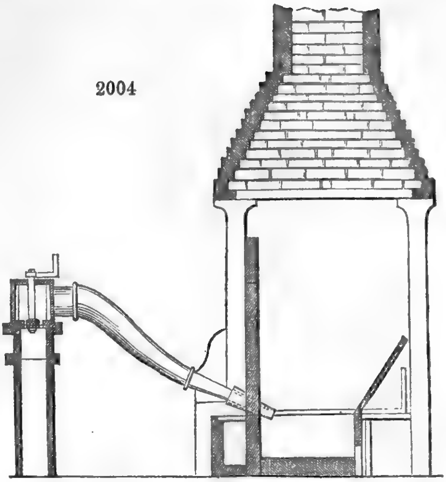
The *charcoal finery* is also worked by the use of the gases to a much greater extent than is generally known. The workman sends his blast directly into the mass of iron, and the charcoal seems to be simply the means by which he is better enabled to manipulate the iron in the finery, and keep it covered, so as to revive the oxidised metal, and thus prevent waste. A few hours spent with any intelligent workman at the side of his charcoal finery would show the wasteful and expensive character of the so-called *new* schemes for converting cast- into wrought-iron by the use of air alone. The late belief in these schemes, by men of high repute and practical knowledge in the trade is a direct proof of the deficiency in knowledge of exact science as at present applied to the manufacture of iron.

The pile was now placed in the hollow fire, and brought to a soft welding or washing heat; again hammered out to 'slabs,' 6 inches wide and three-quarters of an inch thick; these were re-heated, cut up, and afterwards passed through rolls, reducing them to 'bars,' 6 inches by half an inch. These were known in the trade as 'hollow fire iron,' or 'tin-bars.' The result of Mr. Watkin George's improvements was, to reduce the cost and double the production with the same outlay in machinery. All the tin-plates made at this time had the great defect of a rough and smooth side. In the year 1820, Mr. Wm. Daniell found a mode to remedy this defect. Himself a maker of tin-bars and plates, he had observed that the smooth side of the plate was always that corresponding to the flat part of the 'portal,' or 'staff;' he at once, having ascertained this cause, remedied the defect by hammering out the pile, notching it, and doubling it over, so that the tilted blade of the 'staff' was on the top as well as the bottom of the pile. This was the invention of 'tops and bottoms,' and the writer need not remind practical men of the immense sums made by this discovery during the past fifty years.

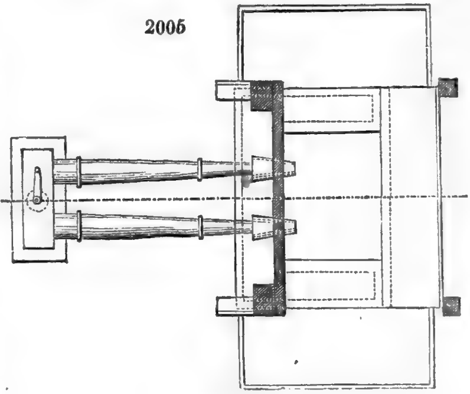
Another improvement since 1807, is the use of the running-out fire; it is still adopted in only a few works. This is represented by *figs.* 2004, 2005, and 2006. *Fig.* 2004 is a vertical section; *fig.* 2005 a horizontal section; and *fig.* 2006 a front elevation. This process saves waste of heat and labour, by running the refined metal at once into the charcoal-finery.

The 'tin-bars' before referred to, 6 inches by half an inch, are heated and run through rollers until they form a sheet of sufficient width; this sheet is then doubled and passed through the rolls, and this repeated until this sheet is quadrupled,—the laminæ are then cut to size, and separated as before described. The writer asks careful attention to the fact, that the last part of the rolling is done when the iron

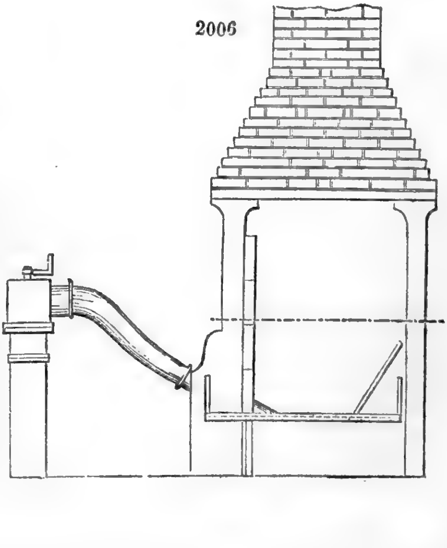
2004



2005



2006

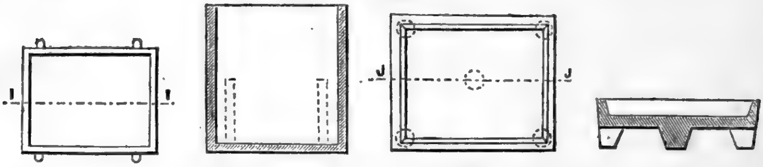


is nearly cold. These sheets are next annealed, and were formerly bent separately by hand, into a saddle, forming two sides of a triangle, thus Λ, and placed in a reverberatory furnace, so that the flame should play amongst them, and heat them to redness; they were then plunged into a bath of muriatic acid, or sulphuric acid and water, for a few minutes, taken out, and drained on the floor, and again heated in a furnace; after which, a scale of oxide of iron separates from the plate during the work of bending them again straight, on a cast-iron block.

The plates should be now free from rust or scale, and are then passed cold through the chilled rolls: this last process is most important, as the ductility and the strength and colour of the tin-plate depend upon this; at this point bad iron will crack or split, and any want of quality in the iron, or skill in the manufacture, will be shown.

A great improvement in the process of annealing was made in 1829 by Mr. Thomas Morgan: the plates were piled on a stand, and covered with a cast-iron box, now termed an 'annealing pot;' in this they were exposed to a dull red heat in a reverberatory furnace for 24 hours. This annealing pot with its stand is represented by *fig.* 2007, in plan and vertical section.

2007



A very important invention in the manufacture of iron for tin-plates, was made by Mr. William Daniell in 1845. About 2½ cwts. of refined metal is placed in the charcoal-finery; this is taken out in one lump, put under the hammer and 'nobbled,' then passed at once through the balling rolls, and reduced to a bar 6 inches square and about 2 feet 6 inches long. This bar is either cut or sawed off in pieces 6 inches long, and these rolled endways to give a bar about 6 inches wide, 2½ inches thick, and 12 inches long, and in this state the inventor calls it 'a billet.' This is heated in a small balling furnace and rolled down to a bar one-quarter inch thick and eleven inches wide, and will be about six feet long. This is taken at once to the tin-plate mill, and the process saves great expense in fuel and machinery.

By the old method of annealing, a box of tin-plates required about 13 lbs. of tin. This is now done with about 9 lbs. for charcoal and 8 lbs. for coke plates.

In referring to tin-plates the standard for quotation is always taken as 1 C. (Common, No. 1.) This is a box containing 225 plates, which should weigh exactly 112 lbs.

The following are the Marks, Weights, and Measurement of the Tin Plates now in common use:—

Names	Sizes	No. in a box	Weight of each box			Marks on the boxes
	Inches		cwt.	qrs.	lbs.	
Common, No. 1	13¾ by 10	225	1	0	0	C 1
„ No. 2	13¼ „ 9¼	„	0	3	21	C 1 1
„ No. 3	12¾ „ 9½	„	0	3	16	C 1 1 1
Cross, No. 1	13¾ „ 10	„	1	1	0	X 1
Two Crosses, No. 1	„ „	„	1	1	21	XX 1
Three „ „	„ „	„	1	2	14	XXX 1
Four „ „	„ „	„	1	3	7	XXXX 1
Common Doubles	16¾ by 12½	100	0	3	21	C D
Cross „	„ „	„	1	0	14	X D
Two Cross „	„ „	„	1	1	7	XX D
Three „ „	„ „	„	1	2	0	XXX D
Four „ „	„ „	„	1	2	21	XXXX D
Common Small Doubles	15 by 11	200	1	2	0	C S D
Cross „ „	„ „	„	1	2	21	X S D
Two Cross „ „	„ „	„	1	3	14	XX S D
Three „ „ „	„ „	„	2	0	7	XXX S D
Four „ „ „	„ „	„	2	1	0	XXXX S D
Waster's Common, No. 1	13¾ by 10	225	1	0	0	W C 1
„ Cross „	„ „	„	1	1	0	W X 1

One of the great items of expense in the manufacture of best iron, as before described, is the cost of charcoal for the fineries. About 1850 the attention of Mr. Rogers was directed to the use of a substitute for charcoal in the finery. Careful thought and experiment led him to the conclusion that some coals could be charred in such a way as to produce a mechanical structure analogous to charcoal, and at the same time when deprived of sulphur might be used in the finery. These experiments resulted in the manufacture of '*charred coal.*' This material has been worked at several of the principal manufactories in South Wales, and declared equal in every respect to charcoal.

The preparation of the '*charred coal*' is very simple. The coal is first reduced to small, and washed by any of the ordinary means: it is then spread over the bottom of a reverberatory furnace to a depth of about 4 inches; the bottom of a furnace is first raised to a red heat. When the small coal is thrown over the bottom a great volume of gases is given off, and much ebullition takes place: this ends in the production of a light spongy mass which is turned over in the furnace, and drawn in about one hour and a half. To completely clear off the sulphur, water is now freely sprinkled over the mass until all smell of the sulphuretted hydrogen gas produced ceases. The result is 'charred coal.' The quantities of 'charred coal' hitherto produced have been made on the floor of an ordinary coke oven, whilst red hot after drawing the charge of coke.

Tin Coating of Iron and Zinc, by Mr. Morries Stirling's patent process. For this purpose the sheet, plate, or other form of iron, previously coated with zinc, either by dipping or depositing from solutions of zinc, is taken; and, after cleaning the surface by washing in acid or otherwise, so as to remove any oxide or foreign matter which would interfere with the perfect and equal adhesion of the more fusible metal or alloy with which it is to be coated, it is dipped into melted tin, or any suitable alloy thereof, in a perfectly fluid state, the surface of which is covered with any suitable material, such as fatty or oily matters, or the chloride of tin, so as to keep the surface of the metal free from oxidation; and such dipping is to be conducted in a like manner to the process of making tin-plate or of coating iron with zinc. When a fine surface is required, the plates or sheets of iron coated with zinc may be passed between polished rolls (as already described) before and after, or either before or after they are coated with tin or other alloy thereof. It is preferred in all cases to use for the coating pure tin of the description known as 'grain tin.'

Another part of the invention consists in covering, either wholly or in part, zinc and its alloys with tin, and such of its alloys as are sufficiently fusible. To effect this, the following is the process adopted:—A sheet or plate of zinc (by preference such as has been previously rolled, both on account of its ductility and smoothness) is taken, and after cleaning its surface by hydrochloric or other acid, or otherwise, it is dried, and then dipped or passed in any convenient manner through the melted tin, or fusible alloy of tin. It is found desirable to heat the zinc, as nearly as may be, to the temperature of the melted metal, previous to dipping it, and to conduct the dipping, or passing-through, as rapidly as is consistent with thorough coating of the zinc, to prevent as much as possible the zinc becoming alloyed with the tin. It is recommended also that the tin, or alloy of tin, should not be heated to a higher temperature than is necessary for its proper fluidity. The metal thus coated, if in the form of sheet, plate, or cake, can then be rolled down to the required thickness; and should the coating of tin or alloy be found insufficient or imperfect, the dipping is to be repeated as above described, and the rolling also, if desired, either for smoothing the surface or further reducing the thickness.

Another part of the invention consists in coating lead or its alloys with tin or alloys thereof. The process is to be conducted as before described for the coating of zinc, and the surface of lead is to be perfectly clean. The lead may, like the zinc, be dipped more than once, either before or after being reduced in thickness by rolling.

Lead and its alloys may also be coated with tin or its alloys of greater fusibility than the lead to be coated.

Crystallised Tin-plate. See MOIRÉE MÉTALLIQUE. It would seem that the acid merely lays bare the crystalline structure really present on every sheet, but marked by a film of redundant tin. Though this showy article has become of late years vulgarised by its cheapness, it is still interesting in the eyes of the practical chemist. The English plates marked F, answer well for producing the *Moirée*, by the following process:—Place the tin-plate, slightly heated, over a tub of water, and rub its surface with a sponge dipped in a liquor composed of four parts of aquafortis and two of distilled water, holding one part of common salt or sal-ammoniac in solution. Whenever the crystalline spangles seem to be thoroughly brought out, the plate must be immersed in water, washed either with a feather or a little cotton (taking care not to rub off the film of tin that forms the feathering), forthwith dried with a low heat, and coated with a lacquer-varnish, otherwise it loses its lustre in the air. If the whole surface is not plunged at once in cold water, but if it be partially cooled by sprinkling water on it, the crystallisation will be finely variegated with large and small figures. Similar results will be obtained by blowing cold air through a pipe on the tinned surface, while it is just passing from the fused to the solid state; or a variety of delineations may be traced by playing over the surface of the plate with the pointed flame of a blowpipe.

Export of Tin Plates in the Year ending 1872 *and the two previous years.*

Countries to which exported	Quantities			Value		
	1871	1872	1873	1871	1872	1873
	Tons	Tons	Tons	£	£	£
France . . .	2,123	3,342	3,941	48,683	97,769	138,569
United States . .	86,929	87,360	85,531	2,075,600	2,770,332	2,745,916
British North America	4,200	4,003	3,343	109,463	142,782	117,276
Australia . . .	5,141	5,094	4,326	137,878	188,015	156,969
Other countries . .	21,212	18,284	23,327	529,001	608,075	794,111
Total . .	119,606	118,083	120,468	2,900,625	3,806,973	3,952,841

TITANIUM (*Sym.* Ti; *At. wt.* 25) is a rare metal, discovered by Klaproth, in Menaccanite, in 1794. Small cubes of a copper-red colour, and so hard as to scratch quartz, which have been found in some of the blast-furnaces in Yorkshire, Wales, and Cumberland, were thought to be titanium; they have recently been shown to be a cyano-nitride of that metal, represented by $TiCy,3Ti^3N$ ($\mathbf{TiCy^2.3Ti^3N^2}$). This metal is very brittle, so hard as to scratch steel, and very light, having a specific gravity of only 5·3. It will not melt in heat of any furnace, nor dissolve, when crystallised, even in nitro-muriatic acid; but only when in fine powder. According to Hassenfratz, it presence in small quantity does not impair the malleability of iron. By calcination with nitre, it becomes oxygenated, and forms titanate of potash. Traces of this metal may be detected in many irons, both wrought and cast. The principal minerals containing titanium, are *sphene*, *brookite*, *anatase*, *rutile*, *iserine* and *menaccanite*. Rutile has been used, with doubtful advantage, in the preparation of steel.

TOAD'S-EYE TIN. A pale hair-brown variety of wood-tin, found near Tregarthy Moor in Cornwall.

TOAST. When bread in thin slices is held in front of a bright fire it is converted into 'toast,' and acquires a characteristic flavour. This appears, according to the experiments of Piesse, to be a product of the destructive distillation of diastase, which all bread contains. When diastase is obtained from bread by alcoholic infusion and precipitation with water, and then heated to 330°, an intense odour of 'toast' is produced.

TOBACCO. It is said that the name 'tobacco' was given by the Spaniards to the plant, because it was first observed by them at Tabasco, or Tabaco, a province of Yucatan in Mexico. Others derive the name from Tabac, an instrument used by the natives of America in smoking this herb. In 1560, Nicot, the French ambassador to Portugal, having received some tobacco from a Flemish merchant, showed it, on his arrival in Lisbon, to the grand prior, and on his return to France, to Catherine of Medicis, whence it has been called Nicotiana by the botanists. Admiral Sir Francis Drake, having on his way home from the Spanish Main, in 1586, touched at Virginia, and brought away some forlorn colonists, is reported to have first imported tobacco into England. But, according to Lobel, this plant was cultivated in Britain before the year 1570; and was consumed by smoking in pipes by Sir Walter Raleigh and companions, so early as the year 1584.

Tobacco is prepared as follows:—The plants are hung up to dry during four or five weeks; taken down out of the sheds in damp weather, for in dry they would be apt to crumble into pieces; stratified in heaps, covered up, and left to sweat for a week or two, according to their quality and the state of the season; during which time they must be examined frequently, opened up, and turned over, lest they become too hot, take fire, or run into putrefactive fermentation.

Respectable tobacconists are very careful to separate all the damaged leaves before they proceed to their preparation, which they do by spreading them in a heap upon a stone pavement, watering each layer in succession with a solution of sea-salt, of spec. grav. 1·107, called *sauce*, till a ton or more be laid; and leaving their principles to react on each other for three or four days, according to the temperature and the nature of the tobacco. It is highly probable that ammonia is the volatilising agent of many odours, and especially of tobacco. If a fresh green leaf of tobacco be crushed between the fingers, it emits merely the herbaceous smell common to many plants; but if it be triturated in a mortar along with a little quick-lime or caustic potash, it will immediately exhale the peculiar odour of snuff. Analysis shows the presence of ammonia in this plant, and fermentation serves further to generate free ammonia in it.

Tobacco contains a great quantity of an azotised principle, which by fermentation produces abundance of ammonia; the first portions of which saturate the acid juices of the plant, and the rest serve to volatilise its odorous principles. The salt water is useful chiefly in moderating the fermentation, and preventing it from passing into the putrefactive stage; just as salt is sometimes added to saccharine worts in tropical countries, to temper the fermentative action. The sea-salt, which contains some muriate of lime, tends to keep the tobacco moist, and is therefore preferable to pure chloride of sodium for this purpose. Some tobacconists mix molasses with the salt *sauce*, and ascribe to this addition the violet colour of the *macouba* snuff of Martinique; and others add a solution of extract of liquorice.

The fermented leaves, being next stripped of their middle ribs by the hands of children, are sorted anew, and the large ones are set apart for making cigars. Most of the tobaccos on sale in our shops are mixtures of different growths: one kind of smoking tobacco, for example, consists of 70 parts of Maryland and 30 of meagre Virginia; and one kind of snuff consists of 80 parts of Virginia and 30 parts of either Mumesfort or Warwick. The Maryland is a very light tobacco, in thin yellow leaves; that of Virginia is in large brown leaves, unctuous or somewhat gluey on the surface, having a smell somewhat like the figs of Malaga; that of Havannah is in brownish light leaves, of an agreeable and rather spicy smell; it forms the best cigars. The Carolina tobacco is less unctuous than the Virginian; but in the United States it ranks next the Maryland. The shag tobacco is dried to the proper point upon sheets of copper.

Tobacco is cut into what is called 'shag tobacco' by knife-edged chopping stamps. For grinding the tobacco-leaves into snuff, conical mortars are employed, somewhat like that used by the Hindoos for grinding sugar-canes; but the sides of the snuff-mill have sharp ridges from the top to near the bottom.

Mr. L. W. Wright introduced a tobacco-cutting machine, which bears a close resemblance to the well-known machines with revolving knives for cutting straw into chaff. The tobacco, after being squeezed into cakes, is placed upon a smooth bed within a horizontal trough, and pressed by a follower and screws to keep it compact. These cakes are progressively advanced upon the bed, or fed in, to meet the revolving blades. The speed of the feeding-screw determines the degree of fineness of the sections or particles into which the tobacco is cut.

Snuff is sometimes largely drugged with pearlashes, and thereby rendered pungent, and absorbent of moisture.

Refuse leaves and roots, such as those of senna, rhubarb, and the like, after their medicinal properties have been extracted in the manufacture of infusions, extracts, and tinctures, by the druggists, were formerly ground, coloured with burnt sienna or yellow ochre, made pungent with ammonia, and then sold in large quantities to the snuff-manufacturers. We have reasons for believing that this fraud is but rarely practised now.

According to the analysis of Posset and Reimann, 10,000 parts of tobacco-leaves contain 6 of the peculiar chemical principle *nicotine*; 1 of *nicotianine*; 287 of slightly bitter extractive; 174 of gum, mixed with a little malic acid; 26·7 of a green resin; 26 of vegetable albumen; 104·8 of a substance analogous to gluten; 51 of malic acid; 12 of malate of ammonia; 4·8 of sulphate of potass; 6·3 of chloride of potassium; 9·5 of potassa, which has been combined with malic and nitric acids; 16·6 of phosphate of lime; 24·2 of lime, which had been combined with malic acid; 8·8 of silica; 496·9 of fibrous or ligneous matter; traces of starch; and 88·28 of water.

In 'Silliman's Journal,' vol. vii. p. 2, a chemical examination of tobacco is given by Dr. Covell, which shows its components to have been but imperfectly represented in the above German analysis. He found, 1, gum; 2, a viscid slime, equally soluble in water and alcohol, and precipitable from both by subacetate of lead; 3, tannin; 4, gallic acid; 5, chlorophyll (leaf-green); 6, a green pulverulent matter, which dissolves in boiling water, but falls down again when the water cools; 7, a yellow oil, possessing the smell, taste, and poisonous qualities of tobacco; 8, a large quantity of a pale yellow resin; 9, nicotine; 10, a white substance, analogous to morphia, soluble in hot, but hardly in cold, alcohol; 11, a beautiful orange-red dye-stuff, soluble only in acids: it deflagrates in the fire, and seems to possess neutral properties; 12, nicotinine.

A strict royal monopoly exists, or existed, in Austria Proper, France, Sardinia, the Duchies of Parma and Lucca, and the Grand-Duchy of Tuscany, and in Portugal, Spain, Naples, and the States of the Church; the license to manufacture is periodically sold to companies, which regulate the prices of tobacco as they please. It will be found that the situation of all these countries where the monopolies and high prices are kept up, is nearly the same, as to illicit trade in tobacco, as in England.

Tobacco *Imported* in 1873:—

	lbs.	Value.
Unmanufactured	81,382,733	2,618,799*l.*
		lbs.
Entered for Home consumption		44,719,756
Deduct Exported on drawback, &c.		535,146
Total		44,184,610*l.*

Duty: containing 10 lbs. or more of moisture in every 100 lbs. 3*s.* $1\frac{8}{10}$*d.* per lb.

Containing less than 10 lbs. of moisture in every 100 lbs. 3*s.* 6*d.* per lb. This was fixed March 27, 1863. The gross amount received in 1873 was 6,949,836*l.*

The total quantities of tobacco retained for home consumption in 1842 amounted to nearly 17,000,000 lbs. Professor Schleiden gives a singular illustration of the quantity of tobacco consumed. North America alone produces annually upwards of 200,000,000 lbs. of tobacco. The combustion of this mass of vegetable material would yield about 340,000,000 lbs. of carbonic acid gas, so that the yearly produce of carbonic acid gas, from tobacco-smoking alone, cannot be estimated at less than 1,000,000,000 lbs.: a large contribution to the annual demand for this gas made upon the atmosphere by the vegetation of the world.

It has been observed by Lane, the learned annotator of the 'Arabian Nights,' (and the observation was confirmed by the experience of Mr. Layard, M.P., the explorer of Assyria), that the growth and use of tobacco amongst Oriental nations has gradually reduced the resort to intoxicating beverages; and Mr. Crawford, in a paper 'On the History and Consumption of Tobacco,' in the Journal of the Statistical Society for March 1853, remarked, that simultaneously with the decline in the use of spirits in Great Britain, there had been a corresponding increase in the use of tobacco.

Year	Population	Quantity of Tobacco consumed	Consumption per head
1821	21,282,960	15,598,152	11·71 oz.
1831	24,410,439	19,533,841	12·80 ,,
1841	27,016,972	22,309,360	13·21 ,,
1851	27,452,262	28,062,978	16·86 ,,

The actual quantity now consumed is not easily obtainable. It has certainly greatly increased, and all medical evidence goes to show that it acts injuriously on the health of the people.

TOBACCO-PIPES are made of a fine-grained plastic white clay, to which they have given the name. It is worked with water into a thin paste, which is allowed to settle in pits, or it may be passed through a sieve, to separate the siliceous or other stony impurities; the water is afterwards evaporated till the clay becomes of a doughy consistency, when it must be well kneaded to make it uniform. Pipe-clay is found chiefly in the Isle of Purbeck, in Dorsetshire, and at Newton Abbot, in Devonshire. It is distinguished by its perfectly white colour, and its great adhesion to the tongue after it is baked, owing to the large proportion of alumina which it contains. See CLAY.

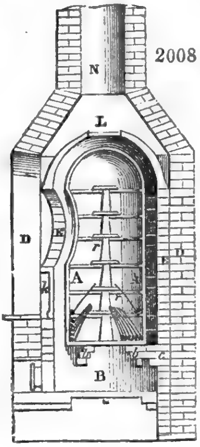
A child fashions a ball of clay from the heap, rolls it out into a slender cylinder upon a plank, with the palms of his hands, in order to form the stem of the pipe. He sticks a small lump to the end of the cylinder for forming the bowl; which having done, he lays the pieces aside for a day or two, to get more consistency. In proportion as he makes these rough figures, he arranges them by dozens on a board, and hands them to the pipemaker.

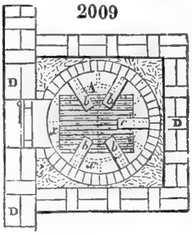
The pipe is finished by means of a folding brass or iron mould, channelled inside, of the shape of the stem of the bowl, and capable of being opened at the two ends. It is formed of two pieces, each hollowed out like a half-pipe, cut as it were lengthwise; and these two jaws, when brought together, constitute the exact space for making one pipe. There are small pins in one side of the mould, corresponding to holes in the other, which serve as guides for applying the two together with precision.

The workman takes a long iron wire, with its end oiled, and pushes it through the soft clay in the direction of the stem, to form the bore, and he directs the wire by feeling with his left hand the progress of its point. He lays the pipe in the groove of one of the jaws of the mould, with the wire sticking in it; applies the other jaw, brings them smartly together, and unites them by a clamp or vice, which produces the external form. A lever is now brought down, which presses an oiled stopper into the bowl of the pipe while it is in the mould, forcing it sufficiently down to form the cavity; the wire being meanwhile thrust backwards and forwards so as to pierce the tube completely through. The wire must become visible at the bottom of the bowl, otherwise the pipe will be imperfect. The wire is now withdrawn, the jaws of the mould opened, the pipe taken out, and the redundant clay removed with a knife. After drying for a day or two, the pipes are scraped, polished with a piece of hard wood, and the stems being bent into the desired form, they are carried to the baking kiln, which is capable of firing 50 gross in from 8 to 12 hours. A workman and a child can easily make 5 gross of pipes in a day.

No tobacco-pipes are so highly prized as those made at Natolia, in Turkey, out of meerschaum, a hydrous silicate of magnesia, of a soft greasy feel, which is formed into pipes after having been softened with water. It becomes white and hard in the kiln. See MEERSCHAUM.

A tobacco-pipe kiln should diffuse an equal heat to every part of its interior, while it excludes the smoke of the fire. The crucible, or large sagger, A, A, *figs.* 2008 and 2009, is a cylinder, covered in with a dome L. It is placed over the fireplace B, and enclosed within a furnace of ordinary brickwork D D, lined with fire-bricks E, E. Between this lining and the cylinder, a space of about 4 inches all round is left for the circulation of the flame. There are 12 supports or ribs between the cylinder and the furnace lining, which form so many flues, indicated by the dotted lines *x*, in *fig.* 2009 (the dotted circle representing the cylinder). These ribs are perforated with occasional apertures as shown in *fig.* 2008, for the purpose of connecting the adjoining flues; but the main bearing of the hollow cylinder is given by five piers, *b*, *b*, *c*, formed of bricks projecting over and beyond each other. One of these piers, *c*, is placed at the back of the fireplace, and the other four at the sides *b*, *b*. These project nearly into the centre, in order to support and strengthen the bottom; while the flues pass up between them, unite at the top of the cylinder in the dome L, and discharge the smoke by the chimney N.


2008


2009

The lining E, E, of the chimney is open on one side to form the door, by which the cylinder is charged and discharged. The opening is permanently closed as high as *k*, *fig.* 2008, by an iron plate plastered over with fire-clay; above this it is left open, and shut merely with temporary brickwork while the furnace is going. When this is removed, the furnace can be filled or emptied through the opening, the cylindric crucible having a correspondent aperture in its side, which is closed in the following ingenious way, while the furnace is in action. The workman first spreads a layer of clay round the edge of the opening: he then sticks the stems of broken pipes across from one side to the other, and plasters up the interstices with clay, exactly like the lath-and-plaster work of a ceiling. The whole of the cylinder, indeed, is constructed in this manner, the bottom being composed of a great many fragments of pipe-stems, radiating to the centre; these are coated at the circumference with a layer of clay. A number of bowls of broken pipes are inserted in the clay; in these other fragments are placed upright to form the sides of the cylinder. The ribs round the outside, which form the flues, are made in the same way, as well as the dome L; by which means the cylindric case may be made very strong, and yet so thin as to require little clay in the building, a moderate fire to heat it, while it is not apt to split asunder. The pipes are arranged within, as shown in the figure, with their bowls resting against the circumference, and their ends supported on circular pieces of clay, *r*, which are set up in the centre for that purpose. Six small ribs are made to project inwards all round the crucible, at the proper heights to support the different ranges of pipes, without having so many resting on each other as to endanger their being crushed by the weight. By this mode of distribution, the furnace may contain 50 gross, or 7,200 pipes, all baked within eight or nine hours; the fire being gradually raised, or damped if occasion be, by a plate partially slid over the chimney-top.

TODDY, *Sura*, *Mee-ra*, 'sweet juice.' The proprietors of cocoa-nut plantations in the peninsula of India, and in the Island of Ceylon, instead of collecting a crop of nuts, frequently reap the produce of the trees by extracting sweet juice from the flower-stalk. When the flowering branch is half shot, the toddy-drawers bind the stock round with a young cocoa-nut-leaf in several places, and beat the *spadix* with a short baton of ebony. This beating is repeated daily for ten or twelve days, and about the end of that period a portion of the flower-stalk is cut off. The stump then begins to bleed, and an earthy vessel (chatty) or a calabash is suspended under it, to receive the juice, which is by the Europeans called *toddy*.

A thin slice is taken from the stump daily, and the toddy is removed twice a day. A cocoa-nut frequently pushes out a new spadix once a month; and after each spadix begins to bleed, it continues to produce freely for a month, by which time another is ready to supply its place. The old spadix continues to give a little juice for another month, after which it withers; so that there are sometimes two pots attached to a tree at one time, but never more. Each of these spadices, if allowed to grow, would produce a bunch of nuts from two to twenty. Trees in a good soil produce twelve bunches in the year; but when less favourably situated, they often do not give more than six bunches. The quantity of six English pints of toddy is sometimes yielded by a tree daily.

Toddy is much in demand as a beverage in the neighbourhood of villages, especially where European troops are stationed. When it is drunk before sunrise, it is a cool, delicious, and particularly wholesome beverage; but by eight or nine o'clock fermentation has made some progress, and it is then highly intoxicating.[1]

TOLU is a brownish-red balsam, extracted from the stem of the *Myroxylon toluiferum*, a tree which grows in South America. It is composed of resin, oil, and benzoic acid. Having an agreeable odour, it is sometimes used in perfumery. It has a place in the Materia Medica.

TOLUIDINE. $C^{14}H^{9}N$ (**$C^{7}H^{9}N$**). A volatile base isomeric with lutidine, formed from toluole, by processes analogous in all respects to those by which aniline is produced from benzole.

TOLUOLE. $C^{14}H^{8}$ (**$C^{7}H^{8}$**). Syn. *Hydruret of toluenyle.* A hydrocarbon produced in the destructive distillation of the resin of tolu. It is also produced by the decomposition of toluylic acid by baryta at a high temperature. Coal-naphtha contains it in large quantity. For its physical properties, see CARBO-HYDRIDES.

TOMBAC, or *White Copper*. An alloy of copper and zinc, containing 85 per cent. of the former and 15 of the latter.

TON. An English weight of 20 cwts., according to the statute, or 2,240 lbs. It varies in different districts:—

South Wales, from 2,400 lbs. to 2,618 lbs.
Ayrshire, from 2,464 lbs. to 2,520 lbs.
North Staffordshire, coal, 2,400 lbs.
Do. do. stone, 2,520 lbs.

Copper ores are sold by the ton of 21 cwts. of 112 lbs. or 2,352 lbs.

In Newcastle the leases are by the ton of 440 bolls of 36 gallons each = 48 tons, 11 cwts. 2 qrs. 17 lbs. statute.

TONKA or **TONQUIN BEAN.** The fruit of the *Dipteryx odorata* affords a concrete crystalline volatile oil (*stearoptene*), called *Coumarine* by the French. It is extracted by digestion with alcohol, which dissolves the stearoptene and leaves a fat oil. It has an agreeable smell, and a warm taste. It is fusible at 122° Fahr., and volatile at higher heats.

TOOTH, ARTIFICIAL MANUFACTURE. Teeth should be made of the best ivory. The following, however, is one of the processes adopted for the artificial manufacture of teeth. Pure quartz is calcined by a moderate heat. When taken from the fire it is thrown into cold water, which breaks it into numberless pieces. The pieces of calcined quartz are ground into fine powder. Next fluor-spar, free from all impurities, is ground up in like manner into a fine powder.

The next step is to mix together nearly equal parts, by weight, of the powdered spar and quartz. This mixture is again ground to a greater fineness. Oxide of tin is now added to it, for the purpose of producing an appropriate colour, and water and china clay to make it plastic and give it consistency. This mixture resembles soft paste, which is transferred to the hands of females, who are engaged in filling moulds with it. After the paste has been moulded into proper shape, two small platina rivets are inserted near the base of each tooth, for the purpose of fastening it (by the dentist), to a plate in the mouth. They are now transferred to a furnace, where they are 'cured,' as it is technically called; that is, half-baked or hardened. The teeth are now ready to receive the enamel, which is applied by women; it consists of spar and quartz which has been ground, pulverised, and reduced to the state of a soft paste, which is evenly spread over the half-baked body of the tooth, by means of a delicate brush. The teeth must be next subjected to an intense heat. They are put into ovens, lined with platina and heated by a furnace, in which the necessary heat is obtained. The baking process is superintended by a workman, who occasionally removes a tooth to ascertain whether those within have been sufficiently baked. This is indicated by the appearance of the tooth.

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[1] Contributions to the History of the Cocoa-nut Tree. By Henry Marshall, Esq., Deputy Inspector of Hospitals.

TOPAZ. The fundamental form is a scalene 4-sided pyramid; but the secondary forms have a prismatic character, and are frequently observed in 4-sided prisms, terminated by 4 planes. The lateral planes of the prism are longitudinally striated. Fracture conchoïdal, uneven; lustre vitreous; colours, white, yellow, green, blue, generally of pale shades. Hardness, 8; spec. grav. 3·5. Prismatic topaz consists, according to Berzelius, of alumina, 57·45; silica, 34·24; fluoric acid, 7·75. In a strong heat the faces of crystallisation, but not those of cleavage, are covered with small blisters, which however immediately crack. With borax, it melts slowly into a transparent glass. Its powder colours the tincture of violets green. Those crystals which possess different faces of crystallisation on opposite ends acquire the opposite electricities on being heated. By friction it acquires positive electricity.

Most perfect crystals of topaz have been found in Siberia, of green, blue, and white colours, along with beryl, in the Uralian and Altai mountains, as also in Kamtschatka; in Brazil, where they generally occur in loose crystals, and pebble-forms of bright yellow colours; and in Mucla in Asia Minor, in pale straw-yellow regular crystals. They are also met with in the granitic detritus of Cairngorm in Aberdeenshire. The blue varieties are absurdly called *oriental aquamarine* by lapidaries. If exposed to heat, the Saxon topaz loses its colour and becomes white; the deep yellow Brazilian varieties assume a pale pink hue, and are then sometimes mistaken for spinelle, to which, however, they are somewhat inferior in hardness. Topaz is also distinguishable by its double refractive property. Tavernier mentions a topaz, in the possession of the Great Mogul, which weighed 157 carats, and cost 20,000*l.* sterling. There is a specimen in the Museum of Natural History at Paris which weighs 4 ounces 2 gros. Topazes are not scarce enough to be very highly valued. See GEMS.

TORBANITE, or *Torbane-Hill mineral.* See BOGHEAD COAL.

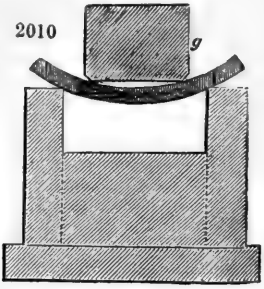
TORBITE. A preparation of Peat, for which works were established at Horwich, in Lancashire. It does not appear that this manufacture was attended with success.

TORREFACTION. Roasting ores to deprive them of sulphur, arsenic, or other volatile substances.

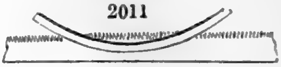
TORTOISE-SHELL, or rather *scale*; a horny substance that covers the hard strong covering of a bony contexture, which encloses the *Testudo imbricata*, Linn. The lamellæ or plates of this tortoise are thirteen in number, and may be readily separated from the bony parts by placing fire beneath the shell, whereby they start asunder. They vary in thickness from one-eighth to one-quarter of an inch, according to the age and size of the animal, and weigh from 5 to 25 lbs. The larger the animal, the better is the shell. This substance may be softened by the heat of boiling water; and if compressed in this state by screws in iron or brass moulds, it may be bent into any shape. The moulds being then plunged in cold water, the shell becomes fixed in the form imparted by the mould. If the turnings or filings of tortoise-shell be subjected skilfully to gradually increased compression between moulds immersed in boiling water, compact objects of any desired ornamental figure or device may be produced. The soldering of two pieces of scale is easily effected, by placing their edges together, after they are nicely filed to one bevel, and then squeezing them strongly between the long flat jaws of hot iron pincers, made somewhat like a hairdresser's curling tongs. The pincers should be strong, thick, and just hot enough to brown paper slightly without burning it. They may be soldered also by the heat of boiling water, applied along with skilful pressure. But in whatever way this process is attempted, the surfaces to be united should be made very smooth, level, and clean: the least foulness, even the touch of a finger, or breathing upon them, would prevent their coalescence. See HORN.

Tortoise-shell is manufactured into various objects, partly by cutting out the shapes and partly by agglutinating portions of the shell by heat. When the shell has become soft by dipping it in hot water, and the edges are in the cleanest possible state without grease, they are pressed together with hot flat tongs, and then plunged into cold water, to fix them in their position. The teeth of the larger combs are parted in their heated state, or cut out with a thin frame saw, while the shell, equal in size to two combs with their teeth interlaced, as in *fig.* 2010, is bent like an arch in the direction of the length of the teeth, as in *fig.* 2011. The shell is then flattened, the points are separated with a narrow chisel or *pricker*, and the two combs are finished, while flat, with coarse single-cut files and triangular scrapers. They are finally warmed, and bent on the knee over a wooden mould, by means of a strap passed round the foot, just as a shoemaker fixes his last. Smaller combs of horn and tortoise-shell are parted while flat, by an ingenious machine, with two chisel-formed cutters placed obliquely, so that each cut produces one tooth. See Rogers's Comb-cutting Machine, 'Trans. Soc. Arts,' vol. xlix. part 2, since improved by Mr. Kelly. In making the frames for eye-glasses, spectacles, &c., the apertures for the glasses were formerly cut out to the circular form with a tool something like a carpenter's centre-bit, or with a crown saw in the lathe. The disks so cut out were used for inlaying in the tops of boxes, &c. This required a piece of shell as large as the front of the spectacle; but a piece one-third of the size will now suffice, as the eyes are *strained* or *pulled*. A long narrow piece is cut out, and two slits are made in it with a saw. The shell is then warmed, the apertures are pulled open, and fastened upon a taper triblet of the appropriate shape; as illustrated by *figs.* 2013, 2014, and 2015. The groove for the edge of the glass is cut with a small circular cutter, or sharp-edged saw, about three-eighths or half an inch in diameter; and the glass is sprung in when the frame is expanded by heat.

2010



2011



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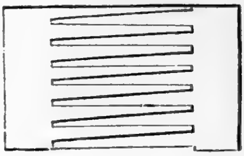
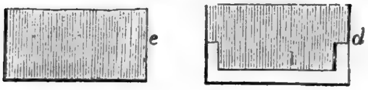
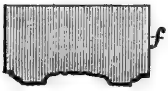
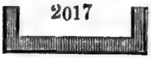


2016

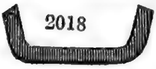




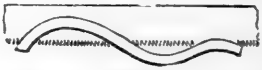
2017



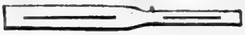
2018



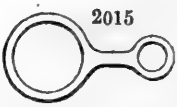
2013



2014



2015



In making tortoise-shell boxes, the round plate of shell is first placed centrally over the edge of the ring, as in *fig.* 2010; it is slightly squeezed with the small round edgeblock *g*, and the whole press is then lowered into the boiling water; after immersion for about half an hour, it is transferred to the bench, and *g* is pressed entirely down, so as to bend the shell into the shape of a saucer, as at *fig.* 2018, without cutting or injuring the material; and the press is then cooled in a water-trough. The same processes are repeated with the die *d*, which has a rebate turned away to the thickness of the shell, and completes the angle of the box to the section, *fig.* 2017, ready for finishing in the lathe. It is always safer to perform each of these processes at two successive boilings and coolings. Two thin pieces are cemented together by pressure with the die *e*, and a device may be given by the engraved die *f* (*fig.* 2016).

TOSSING or **TOZING.** A process in dressing ores, by which they are kept suspended in water by agitation. See Dressing of Ores.

TOUCH-NEEDLES and **TOUCH-STONE** are means of ascertaining the quality of gold trinkets. The touch-needles are bars of known composition, and the touch-stone is black basalt; according to the streak made by the article to be tested, as compared with that made by the needles, its quality is inferred.

TOURMALINE. A silico-borate of alumina and several other bases, usually with fluorine. This mineral is used in the construction of polariscopes. The black varieties are known as *Schorl*, the red as *Rubellite*, and the blue as *Indicolite*.

TOUS-LES-MOIS. A name given to a kind of starch obtained from the *Canna edulis*, one of the *Marantaceæ*, or Arrowroot order.

TOW. See Flax.

TRAGACANTH, GUM, (*Gomme adracante*, Fr.; *Traganth*, Ger.) See Gum.

TRASS or **TARRAS.** A German term for a tertiary earth, probably volcanic, which occupies wide areas in the Eifel district of the Rhine. Its basis appears to be pumice-stone, mixed with fragments of basalt and calcined slate. When powdered it is used, like the *pozzolano* of Italy, as an hydraulic cement.

TRAVERTIN. A white concretionary limestone deposited from springs holding carbonate of lime in solution. Travertin is compact; tufa is a porous body.

TREACLE is the viscid brown uncrystallisable syrup which drains from the sugar-refining moulds. Its spec. grav. is generally 1·4, and it contains upon an average 75 per cent. of solid matter. See Sugar.

TREFOIL, BITTER. One of the clovers which possesses a bitter taste.

TRENT SAND or **WHARPE.** A river sand found in some parts of the Trent, and also in the Severn, and some other places; used for polishing German silver.

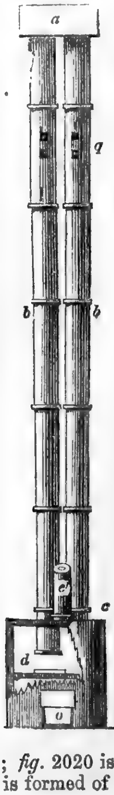
TRIPOLI (*Terre pourrie*, Fr.; *Tripel*, Ger.) is a mineral of an earthy fracture, a yellowish-grey or white colour, composition impalpably fine, meagre to the touch, does not adhere to the tongue, and burns white.

M. Ehrenberg has shown that those friable homogeneous rocks, which consist almost entirely of silica, are actually composed of the exuviæ or rather the skeletons of Infusoria (*animalculæ*), of the family of *Barcellariæ*, and the genera *Cocconema*, *Gonphonema*, &c. They are recognised with such distinctness in the microscope, that their analogies with living species may be readily traced, and in many cases there is no appreciable difference between the living and the fossil forms. The species are distinguished by the number of partitions or transverse lines upon their bodies. The length is about $\frac{1}{288}$th of a line. M. Ehrenberg made his observations upon the tripolis of Billen in Bohemia, of Santafiora in Tuscany, of the Isle of France, and of Francisbad, near Eger.

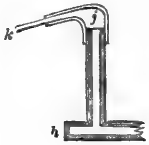
Tripoli is said by Brooke and Miller to be found near Prague in Saxony, in France, Tripoli, Corfu. Tripoli has been confounded by many writers with the English Rottenstone. Mr. Kirwan, in his 'Elements of Mineralogy,' says, 'Mr. Haase who has lately analysed it found 100 parts of it to contain 90 of silicious earth, 7 of argill, and 3 of iron; but the red sort probably contains more iron.'

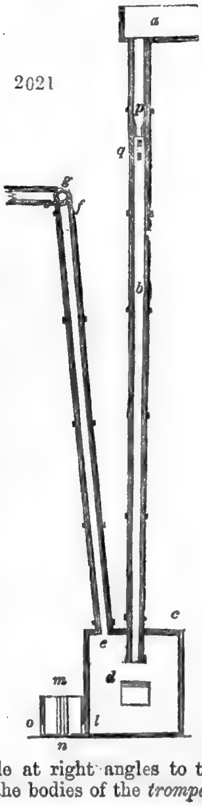
TROMPE, THE. The *trompe*, or water-blowing engine, *figs.* 2019, 2020, 2021, is employed in some of the great metallurgical works of the Continent. *Fig.* 2019 is the elevation; *fig.* 2020 is a vertical section, made at right angles to the elevation. The machine is formed of two cylindrical pipes; the bodies of the *trompe*, *b b*, set up-

2019

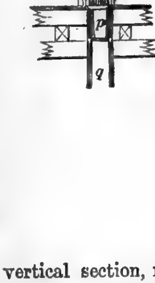


2021





2020



right, called the funnel, which terminate above in a water-cistern *a*, and below in a close basin under *c*, called the *tub* or *drum*. The conical part *p* of the funnel has been called *étranguillon*, being *strangled*, as it were, in order that the water discharged into the body of the trompe shall not fill the pipe in falling, but be divided into many streamlets. Below this *narrow part*, holes, *q q*, are perforated obliquely through the substance of the trompe, called the vent-holes or nostrils, for admitting the air, which the water carries with it in its descent. The air afterwards parts from the water, by dashing upon a cast-iron slab, placed in the *drum* upon the pedestal *d*. An aperture, at the bottom of the drum, allows the water to flow away after its fall; but to prevent the air from escaping along with it, the water as it issues is received in a chest, *l m o n*, divided into two parts by a vertical side-plate between *m n*. By raising or lowering this plate, the water may be maintained at any desired level within the drum, so as to give the included air any determinate degree of pressure. The superfluous water then flows off by the hole *o*. See Aspirator.

The air-pipe *e f*, *fig.* 2021, is fitted to the upper part of the *drum*: it is divided, by the point *f*, into three tubes, of which the principal one is destined for the furnace of cupellation, whilst the other two, *g g*, serve for different melting furnaces. Each of these tubes ends in a leathern pocket, and an iron nose-pipe, *k*, adjusted in the tuyère of the furnace. At Pesy, and in the whole of Savoy, a floodgate is fitted into the upper cistern, *a*, to regulate the admission of water into the trompe; but in Carniola the funnel is closed with a wooden plug, suspended to a cord, which goes round a pulley mounted upon a horizontal axis, as shown in *fig.* 2020. By the plug *a* being raised more or less, merely the quantity of water required for the operation is admitted. The plug is pierced lengthwise with an oblique hole, *c c*, in which the small tube *c* is inserted, with its top some way above the water level, through which air may be admitted into the heart of the column descending into the trompe *p q*.

The ordinary height of the trompe apparatus is about 26 or 27 feet to the upper level of the water-cistern; its total length is 11 meters (36½ feet), and its width 2 feet, to give room for the drums. It is situated 10 meters (33⅓ feet) from the melting furnace. This is the case at the smelting works of Jauerberg, in Upper Carniola.

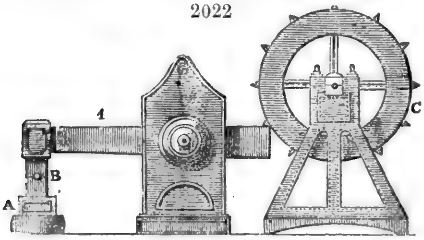
TRONA. A name given by the Africans to Natron.

TROUBLES. Disturbances in the strata, interfering with the progress of work in a coal mine.

TRUFFLES. A mushroom-like vegetable production, found underground in Northamptonshire and elsewhere, but imported as a luxury from Italy.

TUBES. The manufacture of iron tubes for gas, water, and other purposes has become one of extreme importance. Mr. Russell, of Wednesbury, patented a process which has been carried out on a very large scale. In this process plate-iron, previously rolled to a proper thickness, is cut into such strips or lengths as may be desirable, and in breadth corresponding with the width of the tube intended to be formed. The sides of the metal are then bent up with swages in the usual way, so as to bring the two edges as close as possible together. The iron thus bent is then placed in an air or blast furnace, and brought to a welding heat, in which state it is withdrawn and placed under the hammer. *Fig.* 2022, A, is the anvil having a block or bolster, with a groove suited to and corresponding with a similar groove B, in the face of the block, C is a wheel with projecting knobs, which, striking in succession upon the iron-shod end of the hammer-shaft, causes it to strike rapidly on the tube. In this process the tube is repeatedly heated and hammered, until the welding is complete from end to end. A mandril may be inserted or not during the operation. When the edges of iron have been thus thoroughly united, the tube is again heated in a furnace, and then passed through a pair of grooved rollers similar to those used in the production of rods, *fig.* 2022. Suppose a tube D, to be passing through these rollers, of which *fig.* 2023 represents a cross-section, immediately upon its being delivered from the groove it receives an egg-shaped core of metal fixed upon the extremity of the rod E, over

2022



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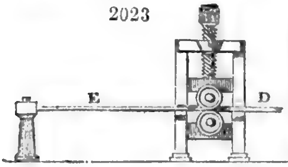

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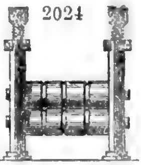


which the tube sliding on its progress, the inside and outside are perfected together. Mr. Cort patented a similar process for the manufacture of gun-barrels.

Brass or copper tubes are formed of rolled metal, which is cut to the required breadth by means of revolving disks: in the large sizes of tubes the metal is partially curved in its length by means of a pair of rolls; when in this condition it is passed through a steel hole or a die, a plug being held in such a position as allows the metal to pass between it and the interior of the hole. Oil is used to lubricate the metal; the motion is communicated by power, the drawing apparatus being a pair of huge nippers, which holds the brass, and is attached to a chain and revolves round a windlass or cylinder. The tube in its unsoldered state is annealed, bound round at intervals of a few inches with iron wire, and solder and borax applied along the seam. The operation of soldering is completed by passing the tube through an air-stove, heated with 'cokes' or 'breezes', which melts the solder, and unites the two edges of the metal, and forms a perfect tube; it is then immersed in a solution of sulphuric acid, to remove scaly deposits on its surface, the wire and extra solder having been previously removed: it is then drawn through a 'finishing hole plate,' when the tube is completed.

Mandril-drawn tubes, as the name indicates, are drawn upon a very accurately turned steel mandril; by this means the internal diameter is rendered smooth; the tube formed by this process is well fitted for telescopes, syringes, small pump-cylinders, &c.

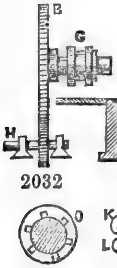
The manufacture in all its details is described by Mr. W. C. Aitken, of Birmingham, in the following article:—

Manufacture of Tubes in Lead, Tin, Iron, Steel and Brass, whether soldered, plain, taper, ornamental, solid, or seamless.

The introduction of water into public and private establishments as provision for heating and ventilating, the use of tubes for the conveyance of gas, the large demands for tubes also required in the construction of locomotive and marine engine-boilers, have been the means of developing what is now an important branch of national industry. Tubes or pipes are essential requisites of the day, and may be said to have originated in the practical application of science to the wants of the present and coming generations: as pipes to let pure water in and carry foul water out, pipes for warming, ventilating, and drainage, pipes to bring in gas, and to carry away the results of its combustion, pipes for the rich man's marble or earthenware bath, pipes for the poor man's brick kitchen, pipes for fountains and cesspools, for arresting conflagration and pestilence, for the locomotive on the iron road, and the steamboat as it cleaves the ocean-wave. This brief allusion to the multifarious uses to which pipes or tubes are applied may be accepted either as introductory to the *modus operandi* or means by which tubes are produced from various metals. There is every reason to believe that in the early stages of tube-manufacture tubes generally were formed by casting, the aperture being produced by means of a core of sand laid in a print in a mould. They were cast in short lengths, and soldered together, or they were turned up from flat sheet-metal and the edges united by means of soldering if lead or brass; or if of iron, they were welded; the methods of manipulation now adopted arising from the increasing demand for such forms of metal.

Lead-pipes were formerly produced by being cast in sand-moulds, a cylinder or 'core' of sand being laid in corresponding to the internal diameter of the aperture. These were cast in short lengths and soldered together, or they were produced from milled or rolled sheet lead and soldered together with soft or plumber's solder at the seam or junction of the two edges of the sheet lead: then followed the process by which the

2029



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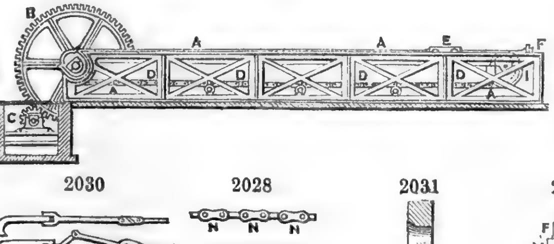

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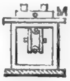

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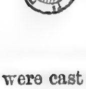

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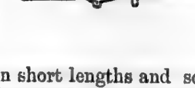

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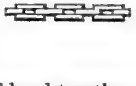

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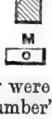

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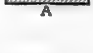
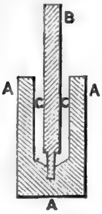


tube was elongated from a thick cylinder, or billet of lead, by means of the drawbench, the billet in its interior being supported by a mandril of steel; and in that condition it was drawn through a succession of wortles or tools which diminished the external diameter of the billet until the desired external diameter of the tube was arrived at. As, however, the drawbench is an important machine in the production of tube formed of every kind of metal, a cut is here introduced to show its construction.

In *fig.* 2025, an elevation of drawbench, A A A A represents the frame of the drawbench; C the pinion connected with the driving shaft of the engine; B the toothed wheel; D D D D, the endless chain; E the clip to which the plyers are attached; F the two snags or standards against which the die M is held in the process of drawing. *Fig.* 2026, represents an end section of the drawbench at F; *fig.* 2028, representation of a section of endless chain; *fig.* 2029, section of wheel and pinion. H represents the driving shaft, and G the pulley or sheaf in which the chain moves. *Fig.* 2030, K shows hook which is inserted into interstices of endless chain at N, into which the plyers or nippers are attached in which the spit, mandril, or metal is placed and held in the process of drawing the tube. *Fig.* 2027 represents the 'snags' or standards against which the tool M is held. *Fig.* 2031 represents section of tool M; *fig.* 2032 section through G showing projections which catch the interstices or apertures in chain, *fig.* 2028, and drag it along; a corresponding pulley or sheaf is placed at I, *fig.* 2025.

2033



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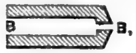
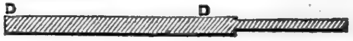
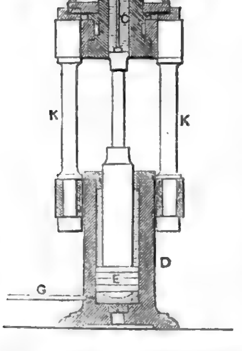




2035

Reverting to the manufacture of lead-tube, the billet was cast in metal moulds or chills, thus, *fig.* 2033, A A A represents metal mould and B the steel mandril; into the space C C, the lead was poured; the result was a casting or 'billet,' when the mould was opened, and the mandril B withdrawn. The result was a hollow cylinder, *fig.* 2034, in section. Into the space B B a mandril was introduced, *fig.* 2035, in form corresponding to its internal diameter, the parallel part of mandril D D being of the length of the intended tube. The 'billet' alluded to was passed on to the mandril D D; and held by the shoulder of the diminishing part thereof in front of the nose of the billet, and on the reduced portion of the mandril a series of 'wortles' or 'dies' were placed, diminishing in diameter to the required external size of the tube; in this condition the mandril and billet was taken to the drawbench, the largest die placed against the snags or rest for the die, and the billet drawn through and thereby reduced in diameter and elongated: then followed drawing through the other and smaller or diminishing dies in succession as described; the last operation consisted in withdrawing the spit or mandril: an easy operation, and simply effected by reversing the billet and using a die, the full size of the mandril to be withdrawn, the drawbench assisting in the operation. By a similar process, **Block Tin** tube, now so largely used in gas-fitting, for liquor-fountains, and other purposes, is still made; its brightness being produced in the process of drawing by a cutting-die, which shaves off a thin portion of the metal and exposes its brilliancy: the polish is given by the dies which follow in succession. It will, however, be evident that the process alluded to is a slow one, and but imperfectly adapted to supply the great demand for lead-pipes now existing. An exceeding rapid process for its production is now adopted, in which an hydraulic press, operating on a molten mass of lead, forces it in its melted state through a suitably-formed annular space, and produces lengths of tube limited only in their length by the quantity of liquid lead operated upon. The process will be best understood by reference to the cut, *fig.* 2036, which consists of a double-ended piston, operated upon by a hydraulic apparatus, a lead furnace, and a nosel or exit from which issues the pipe

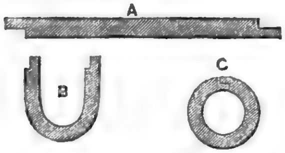
2036



made. Supported on pillars K K stands an arrangement of metal in which is inclosed an annular furnace under C, represented by A A, with provision for introducing fire. In centre, marked C, is the melted lead contained in a cylinder fitted with piston, connected with that of the hydraulic press, D; the lead is introduced at the spout or feeder, B; on the cylinder, C, being filled, the feeder, B, is unscrewed, and a solid plug introduced. The white line ascending through the space, C, is a mandril, which is the size of the interior of the intended tube. K represents suitably-formed dies, the size of the external diameter of the tube required; the space between the interior of the die and the exterior of the mandril is that through which the melted lead is forced which forms the tube, it being formed, congealed, or solidified at the point where it comes in contact with the external atmosphere, the forcing up of the lead being produced by the water in gate-pipe G being connected with the pump which, set in motion, forces the water under the packing of the piston E; this raises it, and it in turn, operating on the piston, which works up in the interior of the cylinder containing the fluid, or melted lead, presses it out from the space between the die and the mandril. As the tube is made it is wound into coils on a revolving drum F, which is placed over the press; the size of the mandril and the die may be changed, and tubes of lead of any size and length can be produced by this ingenious process, alike simple and speedy in its operation.

The Manufacture of Wrought-iron Tube. There is an immense demand for wrought-iron welded tube now universally used in conducting gas for lighting, water, steam for heating, or for boilers for locomotive- and marine-engine purposes (though there are reasons for believing that for the last two purposes the application of good brass tubes as a substitute is on the increase). The first impetus given to the manufacture of welded iron tube arose immediately after the practical demonstration of William Murdock as to the possibility of lighting public establishments by means of gas, consequent on the experiments made by him at Redruth in Cornwall in the year 1792, the facility afforded by iron of being united by welding naturally suggested iron tubes as a means of conveying the new lighting agent. No doubt the idea of applying iron-pipe for the purpose arose from the very great quantity of gun-barrels made for the construction of the 'Brown Bess' guns used in the continental wars terminating in the year 1815. Great quantities of barrels, incapable of standing the necessary charges in proving, were thrown on one side, and when the introduction of gas began to be favourably entertained, these waste barrels were united together by means of screwing the ends of the barrels, and connecting them by means of ferrules of iron screwed internally; they were thus converted or made into long lengths; the ordinary length of gun-barrels permitted of their being readily welded up the joint or seam, when the two edges of the 'skelp,' as the piece of iron was called from which the barrels were made, were brought in contact. Of course the kind of gun-barrels referred to were not of the first class; but for ordinary use, simply a skelp of iron beaten in a groove, or partially turned up by a hammer in a grooved tool placed on the anvil until they formed a half-closed tube of iron, and they were finally lap-joint-welded, *i.e.* the two edges of the skelp, when in a position that they overlapped each other, such operation being performed entirely by manual labour. The next step consisted in application of the tilt-hammer or hammer worked by power, see *fig.* 2022, and eventually the welding and reduction of the billet or turned-up skelp was effected by rolls, see *figs.* 2023, and 2024. However much and numerous the various patents for the manufacture of iron-tube may have operated in improving the production of iron tubing, it is very evident, that of the number many have been abandoned as worthless or too complicated and expensive in their operation. Thus Cook in 1808 suggested three several processes for the making of barrels or tubes: *i.e.* to drill a hole through a solid cylinder of iron, introduce a mandril and then reduce the external surface by drawing down by grooved rolls; to weld up a strip or skelp as already described; or to force a flat disk of iron into a cup-like form, and elongate the same by drawing down or rolling out. In 1811 a patent was taken out in which the turned-up skelp was welded on a grooved anvil or swage, the hammer being moved by power, an internal support being used. Osborne in 1817 used grooved rolls for 'turning up': the mandril was stationary, and held by means of a shield. Russell in 1824 welded by means of a hollow-faced hammer and a tool; the latter held the tube while the operation of welding was being proceeded with: this patent was unsuccessful, and was abandoned. Whitehouse in 1825 suggested the idea that an internal support might be got rid of altogether, and the weld effected in a 'butt' jointed tube by external pressure only; this is the method now generally adopted as being the simplest and best for the production of iron-tubes for purposes of gas-fittings. In 1831, Royl attempted to evade Whitehouse's patents of welding without internal support by using rolls instead of bell-mouth plyers, or compressible tools or dies. In 1826, Harvey and Brown used a long-ended mandril with bit attached thereto, corresponding to the internal diameter of the iron tube which was to be welded. Russell in 1836 attempted to expedite the production of iron tube by turning up the end of the skelp to a tube-like form, and when the iron was at welding heat, on being drawn through the tool, the entire length of the skelp was turned up, and welded by one operation or heating, either by means of rollers or bell-mouthed plyers, as already described. Prosser in 1840 followed in intention the last-described process, using, however, a tool composed of four pulleys, operated upon by pinions, and a long-shanked mandril with a thick end: the end of the skelp was in this process turned up to enter the combined roller die; it was heated and welded, passing over the thick part of the mandril when being welded. A united patent of Russell and Whitehouse, taken out in 1842, and specially adapted for the production of locomotive- and marine-engine boiler tubes, consisted in introducing a mandril of smaller diameter into the turned-up tube, the edges of which were thinned; the mandril lay immediately under the overlapping edges of the joint: the tube being heated, was then passed under rollers, which pressed the laps or edges of the skelp together on the internal support and produced a firm, strong, and substantial joint or weld. In 1844-5, Russell, instead of passing the tube through the tools, used a moveable bed on which the tube to be welded was laid; the mandril in this process was either placed in the interior of the tube, or was held stationary at the point of welding, or immediately at the point of contact or pressure of the rolls, and the tube passing under it was welded: the tube in this process required two heatings to weld it into its entire length. It will be evident that the majority of these patents ring the changes on the roller alternating with the 'plyer' mode of welding; the former method having been used by Mr. Bush in 1780, not for welding purposes as regards tubes, but for the production of lead-tube, being used by him for rolling down the thick billet of lead in order to elongate and reduce it in its external diameter. Of the patents noticed, the majority depend on the use of rollers as a means of welding in connection with an internal mandril, pointing to the conclusion that, previous to the introduction of the amended Patent Law in 1852, such arrangement of tools or welding machines included therein must have formed, as they did, fertile sources of litigation. A somewhat ingenious process for making tubes to be applied for locomotive and marine-engine boiler purposes was carried into execution by the late Mr. Richard Prosser in the years 1852-3. In this process the welding of the tubes was attempted to be got rid of altogether by a process dependent entirely on the accuracy of the preparation of the skelp, and the closing of its edges; the skelp, being placed on the bed of a planing machine, had its two outer edges planed down to half the thickness on the opposite sides of the sheet, thus; see A, *fig.* 2037, a stationary cast-iron grooved bed die, the entire length of the intended tube, with corresponding convex tool, which descended and converted the flat metal into the form represented at B, *fig.* 2037. In this condition a concave die, descending in a similar manner, turned over the edges of the metal, which was eventually forced down, and assumed the cylindrical form as represented at C, as the tightness of the tube was dependent on the accuracy of the planing of the edges of the skelp and the closeness with which these edges were brought together, the only means of retaining these firmly being the cohesion of the joints arising from the pressure of the water in the interior of the boiler. Perfect as these joints were made, the vibration of the engine speedily opened them, and the tube, it is almost unnecessary to add, was not a success.

2037



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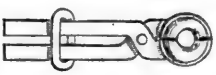

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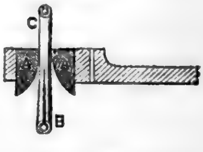
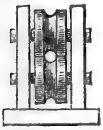


The manufacture of welded 'edge and edge' or 'butt' and 'lap' jointed iron tube is practised as follows:—The iron of which the tube is made is received from the manufacturer of iron in the form, thickness, and breadth required for the tubes of the various diameters and thicknesses of metal necessary for the purposes intended: it is cut into lengths, and then heated to a red heat in a reverberatory furnace of sufficient length to heat the iron at one operation. This furnace is similar in construction to a soldering stove, shown at *fig.* 2047; the heat is also regulated by dampers; it can, however, be raised to a higher temperature. When heated the 'skelp' at its end is beaten into a semi-tubular form, and after passing it through the tool, it is taken hold of with the plyers of the drawbench and drawn through its entire length, the tool either being a pair of rolls, as in *fig.* 2040, or a two-part conical pair of dies united together as a pair of plyers; see *fig.* 2038. In *fig.* 2039 the operation of the die, &c., is shown in welding, after a second heating: A A is section of bell-mouthed tool; B the unwelded tube; C, the portion drawn through the tool or die, and welded in passing through; this completes the manufacture of a 'butt or jump-joint welded tube for gas or the transmission of a fluid in which the pressure is not great.'

In the manufacture of a 'lap' welded tube, the manipulation is more complicated, as the edges of the iron to be welded require to be thinned preparatory to welding, and this is effected by drawing the edge of the sheet against a suitably-formed cutter, which cuts away the desired metal from the opposite sides of the metal, which come together, and form the 'lap' to be welded; see *fig.* 2041. The flat strip is then worked into an oval form in its entire length, the lap being in the centre of the longest diameter of the oval in a transverse section; see *fig.* 2042. Down the centre of this oval-formed tube or unwelded cylinder, a mandril is introduced, A, which forms an internal support: the tube being heated, and the mandril inserted, the tube is passed through rolls to effect and complete the weld. The tube is brought into a cylindrical form by passing through rolls, the reverse or largest diameter being compressed or converted thereby into a cylindrical tube; the rolls are operated upon by screws which permit of their being pressed down into closer contact, and to convert an oval opening in the rolls when asunder or not screwed down into a circular opening, when the rolls are brought into closer contact.

2040



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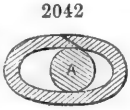
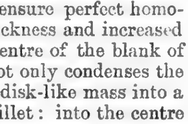


The Manufacture of Steel Tubes for Ordnance, Gun-barrels, and other purposes, has recently been carried into practical usefulness, and more particularly so since the extensive application of the Bessemer process. Ingots of iron produced by the process named are reheated, and hammered in every direction, so as to ensure perfect homogeneity of substance and material, and the ingot reduced in thickness and increased in breadth. To form a cylinder for a heavy gun or rifle, the centre of the blank of steel is operated upon by a punch moved by machinery, which not only condenses the metal operated upon, but in moving radially forms or raises the disk-like mass into a partially-formed solid-ended crude cup, eventually into a steel billet: into the centre of the billet a mandril is inserted, and it is elongated and compressed until the desired length and dimensions of the tube required are arrived at. The lightness and strength of steel in a tubular form suggests its applicability to large-sized shafting hitherto made of solid iron, and to other purposes where great masses of steel were forged solid and bored out. When this process of manufacture is perfected, and consequently cheapened by being more generally applied, steel tubes, cylinders, and hollow shafts will supersede the use of tubes, large solid shaftings, and many tubular articles now made of iron.

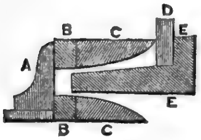
The Manufacture of Brass Tube of the ordinary kind, known as Soldered.—This variety of brass tube, so largely used in the manufacture of gas-fittings, cornice-poles, and other articles in which brass tube is employed in the construction, is made from brass cast in thick strips, and rolled out into sheets of the thickness required. These sheets are cut into ribbons in breadth corresponding to that necessary to produce, when turned up, tubes of the various diameters required. This is done by means of revolving disks of steel, or cutters fitted into a frame, and operated upon by a winch-handle when worked by hand, or attached to a shaft in connection with an engine when moved by power, see *fig.* 2043: E E, represents a cast-iron frame; C C, the revolving disks of steel, or cutters; A, a moveable gauge, in order to determine the breadth and guide the edge of the sheet brass to be cut; B B are pinions which are attached to the spindles which carry the cutters, and D the winch-handle to move the cutters when worked by hand.

2043



When the metal of which the tube is made is thin, and the tube is small in diameter, it is readily formed into a cylinder by simply converting the end of the ribbon into a tange by hammering together the metal which forms the end of the ribbon, in order to allow it to enter the drawing tool, using also an additional funnel-shaped tool to gather up or concave the ribbon in its width. This is assisted by a tapering iron plug held in the funnel-shaped gathering-up tool already alluded to. This arrangement is represented in *fig.* 2044: A representing the snag of drawbench against which the tool rests; B, the tool or die; C, the trumpet-shaped or 'gathering-up' die; E, an iron tapering plug; D, a wedge, in order to prevent E from being drawn in and stopping the metal being turned up in its passage through the 'gathering-up' tool and die, thus converting the ribbon of brass into a tubular form, the edges of the ribbon forming a longitudinal opening down the entire length of the partially-formed tube: this longitudinal opening or slit and the edges of the metal are brought closer together by removing the wedge D, and checking the passage of the ribbon, when the pull of the drawbench brings the two edges of the partially-formed tube closer together. Tubes of larger diameter and of thicker metal, however, require the breadth of metal necessary for their construction to be rendered concave in their entire length, to facilitate the operation of turning the metal up; and this is done by means of a pair of rolls, one of which has on it a series of projecting beads of varying diameters in convexity; the corresponding roll has corresponding concave grooves, as shown in *fig.* 2045. The width of metal is presented to that portion of the roll which will impart the necessary degree of concavity to the strip in its entire length. It is then passed through the rolls, and in passing through is converted into a concave trough-like piece of sheet metal. As in former descriptions in reference to thin metal, the end of the metal is beaten into a tange to be caught by the plyers of the drawbench. This tange is passed through the drawing tool, laid hold of by the plyers, and drawn through the tool; its edges are drawn together by a final pinch or pull of the drawbench. The next operation is that of soldering or uniting the two edges of the metal together: previous to this the partially-formed tube is annealed, and immersed in a solution of weak acid, which removes the scale and grease used in lubricating the metal to facilitate its passage through the tool in turning up from a ribbon to its tube-like form. After the acid is removed by immersion in pure water, the open-jointed tube is in a condition to be soldered at the joint; previous, however, to this it is necessary to bind the tube round with wire at greater or less distances, in order to prevent the seam from opening in the fire when the metal becomes relaxed with the heat of the soldering stove. The wire used is annealed or soft-iron wire; it is passed round the tube, and its ends twisted together; see *fig.* 2046. Along the open joint is laid granulated brass solder, mixed with borax, the latter acting as a flux, at the same time keeping the edges of the joint clean. The solder fuses at a lower temperature than the tube to be soldered. When the solder has been distributed along the seam of the tube (this and the preceding operation usually being performed by women and girls), the tube is in a condition to be passed into the hands of the solderer. The soldering furnace or stove has a provision for a fire 6 or 7 feet long, which burns in a firebrick square tunnel, open at both ends for the introduction of the unsoldered tube at one end, and when soldered to remove it at the opposite end. The fuel used is small coke or 'breezes;' coal until reduced to coke would prevent by its smoke and consequent low heat the fusion of the solder. *Fig.* 2047 shows a section through length of a soldering stove, and *fig.* 2048 a perpendicular section of the same. A A A A A, *fig.* 2047, is brickwork; D D, dampers, to regulate the draught of fire and increase or diminish its intensity; C C are iron bars, on which those rest on which the fire is placed; and B B, the tube which is to undergo the soldering process. The pipe is inserted at one end; the fire playing under and over it, speedily heats the tube; the necessary heat to fuse the solder arrived at, it fuses and unites the two edges of the metal, and the operation of soldering is completed. If the tube has been bound round with wires, these are untwisted and taken off, and in order to get rid of the borax, the tubes are immersed in long troughs of wood, lined with lead and filled with a 'pickle,' composed of a solution of oil of vitriol and water. After remaining in this bath for a limited period, and being rinsed out in water, the superfluous solder is filed off, and the tube is in a condition to receive its final finish in the drawbench, which is effected by placing a drawing-tool so formed that its internal diameter has more friction on the tube than the one used for 'turning up' the tube from the ribbon, the tange of the tube

2044



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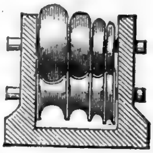

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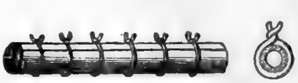

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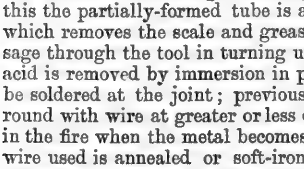

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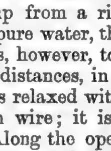
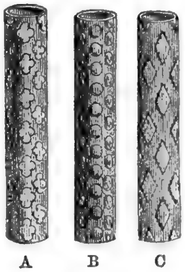


is passed through the tool, and laid hold of by the plyers attached to the chain of the bench, the wheels are thrown into gear, and the tube is drawn through and receives in the operation the fine smooth surface apparent on well and carefully drawn brass tubes.

The Ornamentation of Tubes in Brass, &c.—The action of the drawbench being, as its name indicates, to draw or pull a partially-formed cylinder through a steel tool or die, the tool or die being placed at right angles, the aperture in the centre of the tool being placed parallel to the surface of the top of the drawbench, suggests that if the tube is cylindrical, reeded, fluted, square, oval, hexagonal, polygonal, or angular in its entire length, any of these forms may readily be produced, by simply substituting a draw-plate, the aperture of which corresponds to the external configuration of the desired form of the tube. Tubes which have spiral, concave, or convex twists or threads, traversing their entire length, however, require peculiarly formed tools or dies, and an arrangement in their use to meet the requirements of the desired style of ornamentation.

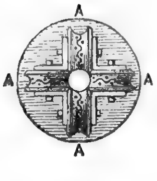
2049



Tubes shown in *fig.* 2049, A B C, are produced from metal, first ornamented by the introduction of perforated sheet zinc between two sheets of metal, and in that position the three sheets are passed through a pair of rolls, the perforated zinc, by the pressure in rolling, being forced into the surface of the brass to be ornamented; the raised portions of ornament in relief; as the quatrefoils, disks, and diamonds, corresponding to the perforations in the zinc introduced between the two sheets of brass to be ornamented. This style of ornamentation of flat metal was introduced by R. F. Sturges, of Birmingham, in the year 1852, and is identical with the process employed in the production of the plates used to produce impressions from natural objects, and known as Nature-Printing. The same effect would be produced by steel rolls cut with ornamental devices on their outer circumference, but the expense of such rolls being very great, the perforated zinc, considering the limited character of the demand for such tubes, is more economical. The ornamental metal being cut up into the breadth required, is made into tube by the process already described as that by which ordinary soldered cylindrical brass tube is made.

Another variety of ornamental tube is produced by a very ingenious process introduced also in the year 1852, by Mr. Fearn. In this process the ornament is impressed on the surface of the tube after it is made: the tool used is formed by a construction of rolls as shown at *fig.* 2050, the internal or hollow surface of the rollers which press upon the tube being cut with the necessary design, the cylindrical or other tube to be ornamented is supported internally by a mandril, and in passing it through the combined tool or die, the rollers, A A A A, revolve and indent the design cut on their circumference into the surface of the plain tube to be ornamented. *Fig.* 2051 shows the style of ornament produced by this process: A being produced on a steel mandril as an internal support; in B and C the convexity or relief of the ornamental beads being greater, it is produced by substituting for the incompressible steel mandril a filling of pitch and resin; the number of rolls may be diminished, or the designs on the concave surface of the rollers may be varied according to the style of ornament desired. It is unnecessary to state that the rollers are formed of the best steel, and are carefully tempered after the die-sinker has cut the design thereon.

2050



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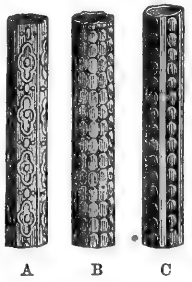

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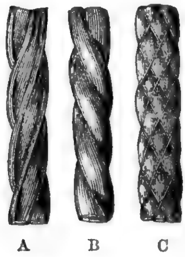
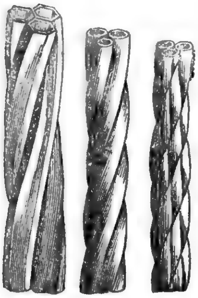


When the ornamentation desired consists of series of reeds or flutes traversing spirally and screw-like, familiarly known as 'twisted tube,' and largely used in the construction of mediæval and other gas-fittings, &c., the tool represents a screw-nut, which is made to revolve by attachment to a hollow spindle; the cylindrical tube is firmly held by the artizan when passing through the tool, and the thread is impressed into the tube, or rather is indented in its passage through the tool or die, the tube being lubricated with oil or tallow to aid the indentation and prevent the projecting thread in the die from cutting or tearing the metal of the tube subjected to its operation. These tools or dies are not made of steel, but of chilled cast iron, their production by the process of casting being more easily effected than by their being cut in cast steel; the friction being reduced to a minimum by the hollow tube yielding readily to the pressure of the convex threads of metal in the die: the characters of such tubes are represented in *fig.* 2052. A and B are the result of once passing the tube through the tool; C showing a diamond raised in centre, is produced by first passing the tube through a tool with the thread right-handed, and then through a tool in which the thread is left-handed, or in the reverse direction or inclination to that through which it was previously passed.

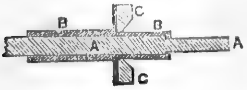
2053



The tubes, *fig.* 2053, are formed of three separate tubes united together, each component tube being first drawn as a separate tube: A being composed of three six-fluted tubes, produced by being drawn through a correspondingly shaped die; B by ordinary separately drawn plain tubes; and in C the three tubes, in addition to the ordinary process of drawing, are subjected to the operation of twisting as already described in the last paragraph (under the head of twisted tubes); the three tubes, eventually forming one united tube, are then arranged parallel to each other and the rope-like appearance of the tube, when finished, is produced by uniting them together by twisting, as strands in an ordinary rope, each tube being filled with pitch and resin to preserve its primitive tube-like form, and prevent its collapsing in the process of uniting the three tubes into the rope-like appearance when finished.

The Manufacture of Mandril-drawn Tubes, or Tubes perfectly cylindrical in their internal and external diameters.—This variety of tube, is chiefly made in brass or copper: in the former material principally used in the manufacture of optical instruments, more particularly telescopes, dependent for their perfection in working on tubes of the utmost degree of accuracy and perfectly cylindrical form, to ensure steadiness when in work; large quantities of mandril-drawn tubes are also used for the barrels of garden and other syringes, telescopic hearth-brushes and toasting-forks, &c.; while ordinary soldered jointed brass tube could not be successfully used, or if used, would require an amount of labour to fit it for the purpose, obviously out of place with the expeditious modes of working now in existence. The elasticity resulting from the process of mandril-drawing, is another advantage in connection with this process, arising from the condensation of the particles of the brass of which the tube is made, these being forced down or compressed by the action of the unyielding steel tool, and the equally unyielding mandril or spit, which internally supports the ordinary brass tube subjected to the process. An ordinary brass tube is unequal in thickness internally throughout its entire length; the two edges of the strip from which it is made and where it is soldered, are clearly seen; and it is evident that anything working piston-like therein, would do so only imperfectly. The manufacture of light brass mandril-drawn tube is practised as follows: A carefully selected and well-forged cylinder of steel is turned to a perfect cylinder by means of a slide rest, and carefully polished; the brass tube made in the way already described, is slipped on the mandril: in this position the mandril and sheath of brass is presented to the die in the drawbench, and is drawn through the tool which forms the outside surface of the tube, compressing the metal, reducing the thickness, and compelling it to embrace the steel mandril or internal support. The result is an elastic brass tube, suitable for the purposes already enumerated. The air being expelled between the tube and the mandril, considerable difficulty arises in releasing the tube from the mandril, and this is effected by means of a collet or collar a little larger than the steel mandril, but less in aperture than the tube: the collet is placed in position of the drawing tool, the reverse end of the mandril being operated upon, as in drawing the tube, the result is that the tube is withdrawn from its internal support, and if the mandril has been correctly turned, a perfectly cylindrical tube is the result of the preceding operations. In *fig.* 2054 the arrangement of mandril and tube to be drawn, and tool, are shown: A A, represents the mandril; B B, the brass to be operated upon; C C, section of the tool; the thickness of line to the left of the tool C C indicates that part of the brass which has not been subjected to the operation of the drawing tool. The release of the drawn tube is shown in *fig.* 2055; the collar or collet C is substituted in the drawbench for the tool shown in the preceding *fig.*; the thick end of mandril A, passed through this, is taken hold of by the plyers of the drawbench; the end of the metal of the tube presents a resistance, while the force of the drawbench drags out or releases the mandril from the drawn tube. Mandril, or drawn 'inside' and 'out' tubes, as they are familiarly called by the 'users,' may be made of any form or size. When of extra thick metal, very powerful, slowly moving drawbenches are required.

2054



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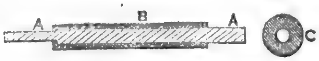
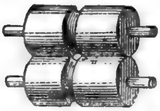


The Manufacture of Patent Brass-cased Tube, or iron tube, cased with brass.—This variety of tube—largely used in the construction of articles in which the external appearance of brass is desired with the strength of iron, as in balustrades for stairs, railings of various kinds, picture-rods, window and other rods, and bedsteads, chairs, and other articles of furniture made in metal of a portable character, and otherwise—was introduced to the brass-foundry trade of Birmingham in the year 1803, and is stated to have originated in the observation of the difficulty of removing a mandril-drawn brass tube from the steel mandril on which it was drawn. The inventor, Sir Edward Thomason, was largely engaged in the silver and plated ware manufactures in Birmingham. As a manufacturer of sliding hearth-brushes, toasting-forks, and other articles telescopically formed, he used large quantities of mandril-drawn tubes, and in the production of such tubes, and the difficulty of getting these off the internal support, the manufacture of patent tube originated. Thomason first also originated the idea of covering solid iron rods with copper and brass, with the intention of their being used instead of solid copper bolts for ship-building purposes. Though unsuccessful as regards the application of iron-cased bolts for the purpose, solid iron rods cased with brass became, and have become, an article of large consumption in the form of the rods which retain the carpetings on stairs. Eventually an iron tube took the place of the solid iron rod, and the manufacture of cased tube took its place as an article of extensive demand for the purposes already named. The manufacture of patent cased brass or iron tube is thus practised:—Sheet iron of good quality, if for articles which do not require to be bent in manufacture, as in rods for pictures, straight railings, &c.; but if the tube is to be bent, charcoal-iron is selected; the sheets of iron are cut up with circular cutters, as shown at *fig.* 2043; and the ribbon arising from the cutting or slitting of sheet iron is concaved in its entire length by passing it through rolls, as shown in *fig.* 2044. It is drawn into tube at the drawbench, in this state: if the tube is intended for articles which are to remain straight, the iron tube is in a condition to allow of its receiving its case of brass; if it is intended that the tube should be bent, the iron tube is soldered together at the seam, as already described in the manufacture of soldered brass tube, the brass sheath intended to cover the iron tube or to case it with, is made of such an internal diameter as will slide over the iron tube it is intended to 'case' or cover, the brass case being turned up, made, and soldered, as already described in the manufacture of soldered brass tube. The brass sheath is then slid over the iron tube, and in this position the end of the two united tubes of iron and brass is passed through the drawing tool: the pressure resulting from the action of the drawbench causes the external brass sheath or tube to embrace firmly the iron tube in its interior, and an externally brass and internally iron tube is produced thereby. During the many years this branch of tube manufacture has been practised, no change or improvement has been made in its manipulation—if we except that, within the last few years, hoop-iron has been substituted in the manufacture of second-rate cased tube, instead of cutting up the broad sheet-iron as formerly.

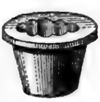
Taper Tubes of Brass or Iron.—This form of tube, formerly made entirely by hand, is now drawn with ease and facility. The old method of production consisted of cutting out the metal from the sheet requisite to produce the desired taper tube. It was then malleted into a taper tubular form, and the metal soldered together at the junction; then, after the extra solder was removed, it was hammered on a taper mandril or stake, as in use among tinmen. Many ingenious drawing tools were made for the purpose of producing taper tubes. These consisted of dies made in sections, or various pieces; they were united in frames, and when used in the drawbench the parts of the die were operated upon by springs, which permitted of their expansion as the taper increased in the tube and mandril intended to be drawn. Such tools,

2056



however, never produced good taper tubes. An after invention consisted in using a pair of rolls with diminishing grooves on their diameter or circumference, and presenting the taper mandril with its sheath of metal at its smallest diameter to the narrowest part of the groove; the revolution or partial revolution of the rolls compressed the metal sheath to the mandril and produced a taper, but still irregular taper tube. This method was patented by Henry Osburn so far back as the year 1813. It, however, seems to have been lost sight of, from the limited demand for taper tubes at the period, and the same process was revived by Church and Harlow in 1841. Though great numbers of taper tubes so made are still produced, it is obvious that, from the very nature of the action of the rolls, the production of taper tubes is limited to those of a purely tapering, externally smooth cylinder; and it would be impossible to produce either reeded, fluted, or twisted tapering tubes by the rolling process. The means, however, by which nearly every variety of tapering tubes can be produced, was effected in 1850 by John Ward, who in that year suggested, instead of an expanding tool made up of a complication of segments of steel, operated upon by springs, or that of the rolling process as already described (see *fig.* 2056), the production of a tool, draw-plate, or die formed in one piece, and of block tin cast in a metal mould. This tool, placed in the position of a 'die' in the drawbench, by the expanding yet compressing property of the metal of which it is made, forces the metal of the sheath to be converted into a taper tube, and into every groove or reed in the internal mandril or support on which the sheath or case to form the taper tube is placed. By the same process, also, tapering tubes with convex or concave twistings, threads, or reeds on the outer diameter can also be produced by the application of a swivel on the drawbench chain, which permits the mandril and its case of metal to revolve in its passage through the tool, the tool remaining stationary. The process may be described as follows:—The die or mould to produce the block-tin tool is formed of metal; the aperture in its centre is tapering—cylindrical if for a plain round taper tube—or if reeded, fluted, or twisted, a metal core with its requisite reeds, flutes, threads, or twists is introduced into the centre of the mould, and the tin poured in: the result is a cast, the interior of which is a copy of the mandril, and also of the external contour of the desired tube. *Fig.* 2057 shows external appearance of the tool when cast, and *fig.* 2058 its internal configuration, depending on the plain or ornamental character of the tube. The sheet brass or iron, being cut to the required diminishing breadth, is turned up and soldered at the joint, after the removal of the wires which held the edges of the partially-formed tube together, and the extra solder, the case to form the intended taper tube, &c., is placed on the mandril. In *Fig.* 2059, A A represents the sheath of brass to form the taper tube; B B, the mandril; the tool is then placed in the proper position in the drawbench, the end of the mandril forced through it, and taken hold of by the plyers attached to the chain; the tool expands and compresses the sheath against the internal mandril, clinging, yet expanding with the increased diameter of the taper of the tube and mandril it is drawn through. The result is a perfectly-formed taper tube, a perfect copy externally of the mandril on which the tube is placed. If the mandril is of an ornamental spiral construction, provision is made, as has been already stated, to admit of a screw-like revolution to indent the metal case into the concavities or threads cut on it externally, *i.e.*, the tool representing a stationary nut, and the mandril and its covering a screw in motion.

2057



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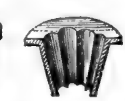

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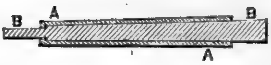


Finish of Cased and other Brass Tubes.—As regards the mode of finish adopted for tubes of which immense quantities are sent out in long lengths, especially of the iron cased with brass variety, it has been the custom of the trade to finish such by means of hand-labour only; the artizan engaged in the process using 'floats,' or files cut in one direction only, for the purpose of the removal of the external skin preparatory to polishing. One house only has applied or substituted a machine for the purpose of finishing tube. *i.e.* that of W. Tonks and Sons, Birmingham. Their machine is self-acting. The tube to be floated is attached to a horizontal bed: the floats, five in number, move parallel, and in a longitudinal direction. Each in its operation passes a little into the space previously floated; the tube is turned by the machine, and a new surface is exposed to be operated upon. The next operation after 'floating' is polishing, which is either effected by hand with list passed round the tube, the tube being lubricated with rotten-stone and oil, or (in the finish of large-sized tubes) an internal buff or hole lined with list or felt, revolves by machinery: the tube being passed in, is polished by the revolution of the buff; the final polish is given by dry list, with powdered dry rotten-stone. Brass tube when finished by burnishing is floated, then scoured with wet pounded clay crucible; then burnished by steel burnishers, gall being applied to hinder their scratching. The last method gives the most brilliant style of finish; by either mode of finish, they are protected from oxidation by a lacquer applied with a camel's-hair brush when the tube is heated, which is done either by laying the tube to be lacquered on a hot iron plate, or by passing through its interior a jet of steam. On cooling, the protection is perfect and the finish completed.

Solid Brass Tube, i.e. brass tube drawn without seam, as used for locomotive- and marine-boiler purposes, &c.

In 1780, Matthew Bolton suggested the introduction of tubes into steam-engine stationary boilers. Trevithick in 1815, in his experiments on engines for locomotive purposes, suggested and applied pipes or tubes, but placed them perpendicularly. Gurney, Summers, and Ogle, in their experiments used also tubes; and George Stephenson in his 'rocket' engine, adopted the almost present arrangement of the tubular boiler. By the ordinary, or soldered brass-tube process, the tubes so produced not unfrequently leaked at the joint or seam from imperfect running of the solder, and the production of a 'solid' or seamless tube became a desideratum. Iron tubes speedily become corroded by the surrounding water in the boiler, and the necessity for finding a substitute in a tube of a material not liable to oxidise and of sufficient strength to resist the exigencies of wear and tear, became a desideratum. Economically, also, the brass tube is in the end cheaper, as the old tubes are taken back by the manufacturers in exchange for the new at a trifling advance in order to cover expense of re-manufacture. Up to the year 1838, tubes for locomotive- and marine-engines were either formed of welded iron, or of brass tube produced by soldering at the joints. In that year, however, Mr. Green of Birmingham conceived and carried into practice the production of seamless brass tubes, in a manner akin or similar to that already described in the production or manufacture of lead and block-iron tube; *i.e.* he cast the brass or copper 'billet,' from which the future tube was to be made in moulds, inserted a mandril into the aperture produced by the sand 'core,' made an alteration in the drawbench, increasing its strength, and operated on its motion by reducing the speed, thereby increasing its power, in order to overcome the stubborn nature of the brass or copper billet operated upon. By reference to cut of drawbench, *fig.* 2025, the large wheel is not operated upon in the manufacture of solid brass tube, by a pinion as shown, but by an endless screw which worked into corresponding threads on the outer surface of the large wheel, and the die was formed not of one, but four parts, *i.e.* as four revolving pulleys placed at an angle to each other, forming a round hole or die in the centre; the brass billet or copper with its mandril similar in form to that already shown. It was then subjected to the action of the drawbench, and gradually reduced by the action of the four-roll tool to the desired external size and the strength of metal desired. Repeated annealings are required in the process of drawing, in order to restore the ductility of the metal of the partially-drawn billet, which is eventually converted into the finished locomotive tube. The metal or brass of which these tubes are composed is made from the best copper and zinc or spelter, as such tubes are replaced every three years; when worn out they are sold to manufacturers for reconversion into similar tubes, or command good prices for raw material, to be used for other purposes in the brass foundry trade.

Another method or process for the manufacture of solid brass tube is also in use, which was introduced in 1852 by G. F. Muntz, junior, and made from the metal familiarly known as 'Muntz's' metal, which possesses the property of being worked, rolled, or manipulated at a low red heat. (See MUNTZ METAL and SHEATHING.) In this, as in Green's process, the raw material is presented in 'billet' form for manufacture into finished tube. This process may be described as follows:—

The 'billet' out of which the future tube is intended to be made is cast in an iron mould with a sand-core: the billet is oval in form, the metal being thickest on the two largest surfaces of the oval. The billet being cast, and the sand removed from its interior, the interior is coated with a wash of lime-water and salt. This prevents the adhesion of the interior surfaces of the metal together in the process of rolling the billet to the length of the intended tube. This is effected by means of rolls grooved in their circumference. In the ordinary process of rolling metal, it will be observed that it is simply elongated by the thickness being reduced, but its breadth is not increased; the thickness of the metal of the 'billet' in the upper and under side therefore provides for this, and the result of the first rollings is to reduce the metal on the upper or under side to the same thickness as the sides. The oval billet being rolled into a flat strip or bar, has then one end opened to the length sufficient to admit of the introduction of a thick-ended mandril. With this introduced, the opened end of the tube is presented to the rolls; the thick part of the mandril retained in the tube at the point of pressure; the tube is drawn on and opened throughout its entire length. The position of the tube in the opening-up of the bar is the reverse of the previous operation, being presented in its largest diameter to the action of the rolls, or at right angles to the preceding operation. The adhering webs or fins consequent on this mode of production being removed, the tube is again passed through rolls, to produce it in form perfectly cylindrical, a mandril in the interior assisting the operation. All the operations in this variety of solid tube are conducted when the metal is at a low red heat, the metal of which these tubes are made, or Muntz's metal, consisting of copper, with a large percentage of zinc or spelter, imparting to it the property of being rolled at the temperature named, much facilitating the rapidity of production.

It may not be uninteresting to know that nearly all the locomotive-engines in use on the railroads of the United Kingdom are fitted up with seamless brass tubes. If to these are added the quantity of seamless brass tubes in use in the steamboats of the United Kingdom also, the united weights of these tubes gives a total of upwards of 20,000 tons of solid or seamless brass tubes in use by the various railway companies, steam-boat proprietors, &c., of this country. The production of solid brass tube in Birmingham, for these purposes alone, amounts to upwards of 8,000 tons annually.

A very admirable variety of solid or seamless *copper* tube is now produced from the worn-out copper rollers used by calico-printers for printing cotton fabrics. The old roller, with the rib which holds the roller on the printing spindle, in the operation of printing, taken out forms the billet; it is reduced in outer diameter, its internal diameter depending on the size of the internal mandril used, the reduction being effected as in the manufacture of Green's tube by powerful draw-benches. As in Green's tube, also, repeated annealings are required in the operation of reduction or drawing down to the size of tube required. This method of producing seamless copper tube from previously waste material was introduced in 1850, by the late Thomas Attwood: the density of the material of which the tube is formed, good at first, as being formed of wrought copper, is further solidified by the *modus operandi* in converting the worn-out roller into a tube for steam purposes. When subjected to great pressure it is unequalled in service.

In conclusion, as regards the manufacture of brass and copper tube but little remains to be stated. Messrs. Alexander and Henry Parkes patented the addition of phosphorus and manganese to the alloy of brass and zinc, out of which locomotive and marine boiler-tubes are made, which they state improves the metal, imparting to it superior cohesive properties, and also solidity. The direction recently given for locomotive and marine engine-tubes is towards tubes containing a larger proportion of copper than even in those of 'Green's' mixture. It is stated, if the percentage of copper is increased, the tubes may be made lighter in material, and will be less likely to be operated upon by the sulphates in the fuel. Finally, if certain preliminary details as to the casting of the 'billets,' from which the solid or seamless tubes are drawn, or in raising the 'billets' up from thick disks of rolled metal, but little remains to be recorded as respects the improved manipulatory operations in the manufacture of brass or copper tubes.

TUBULAR BRIDGES. In the fourth edition—the last published during the lifetime of Dr. Ure—there was a long article bearing the heading of FAIRBAIRN'S TUBULAR BRIDGES. This article no longer appears. In the first place, it ought never to have found a place in a work which has nothing whatever to do with Engineering Science. Such was the introduction to the article as it appeared in the fifth and sixth editions of this Dictionary. The article, which was written with great care by the Editor himself, after several interviews with both Mr. Robert Stephenson and Mr. Fairbairn, was acknowledged by both these eminent engineers to give the most correct account of the merits of each of them, in the construction of these remarkable works. Those who may be interested in this question are referred to the last edition of the Dictionary: the article having been withdrawn from this edition to make room for matter which belongs more especially to Art, Manufactures, or Mines.

TUE-IRON, also *Tuiron* and *Tuarn.* The old name for the blast-hole, or twyer, or tuyère of a blast-furnace.

TUFA. A deposit of calcareous carbonate from springs and streams. Also, a volcanic product. See MORTAR, HYDRAULIC.

TUGMUTTON. A wood resembling box, which was imported and used for making ladies' fans. It does not appear to be now known in the trade.

TULA METAL is an alloy of silver, copper, and lead; made at Tula in Russia.

TUNGSTEN or **WOLFRAM.** (*Tungstène*, Fr.; *Wolframium*, Ger.) *Symbol* Ts or W; *at. wt.* 92. Its name is derived from the principal mineral from which it is obtainable—*Tungsten* (Swedish *tung*, 'heavy,' *sten*, 'stone,') or *Wolfram.* This metal was discovered by the Brothers De Luyart, about 1784, shortly after the discovery of tungstic acid by Scheele, from whom it has been sometimes called *Scheelium.* It is never found in the native state, but is produced by a variety of processes. First, and most easily, by mixing the dried and finely-powdered tungstate or bitungstate of soda with finely-divided charcoal, such as lamp-black; placing the mixture in a crucible lined with charcoal, covering it with charcoal in powder, and then exposing the whole to a steady red heat for two or three hours. On removal of the crucible and cooling it, a porous mass is found, from which the soda is removed by solution in water, and the unconsumed carbon is separated by washing it off, the metal being left as a bright, glistening blackish-grey metallic powder. It may also be obtained by treating tungstic acid in a similar manner, or by exposing the acid at a bright red heat, in an iron or glass tube, to a current of hydrogen gas. Tungsten is one of the heaviest metals known, its specific gravity being 17·22 to 17·6. It requires such a very high temperature for fusion that it has never yet been obtained in mass, more commonly as a fine powder, but sometimes in small grains. It is not magnetic. It is very hard and brittle. Alone it has not been rendered available for any useful purpose, but it has lately been employed for the manufacture of certain alloys. Tungsten is comparatively a rare substance, and is remarkable for the very limited extent to which in nature it is found to have been mineralised by combination with other substances. In none of these does it exist as a salifiable base, but as an acid, as in wolfram, Scheelite, yttrotantalite, and the tungstate of lead.

The most common ore of this metal is *wolfram*, known also to the Cornish miner as 'cal' or 'callen.' It is most commonly found associated with tin ores, which contain besides the black oxide of tin or cassiterite, the metallic minerals, arsenical iron, copper, lead, and zinc sulphides: but its peculiarly characteristic associate is the metal molybdenum, for the most part mineralised as a sulphide. This metal is remarkable in connection with tungsten as producing isomeric compounds, and as having both its equivalent and its specific gravity equal to about one-half that of tungsten, they being, respectively, as follow: equivalents, W 92, Mo 49; sp. gr. W 16·22, Mo 8·615.

Amongst miners wolfram has the reputation of being an abundant mineral, but it is comparatively rare, schorl, specular and other iron ores, and gossan being often mistaken for it. From its association with tin ores, it has been until lately the source of great loss to the miner, as it was found quite impossible to separate it from the ore in consequence of its specific gravity, 7·1 to 7·4, being so near to that of black tin, 6·3 to 7·0.

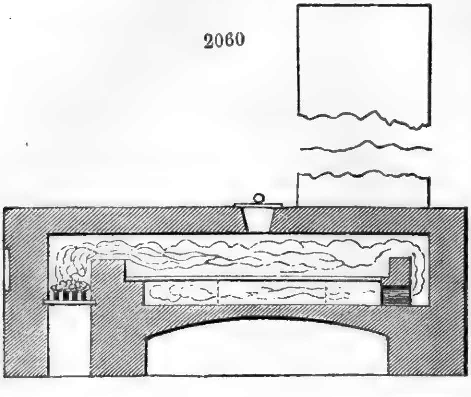
Pryce, in his 'Mineralogia Cornubiensis, 1778,' says: 'After the tin is separated from all other impurities by repeated ablutions, there remains a quantity of this mineral substance (gal), which being of equal gravity cannot be separated from the tin ore by water, therefore it impoverishes the metal and reduces its value down to 8 or 9 parts of metal for twenty of mineral, which without its brood, so called, might fetch twelve for twenty.' This description of tin ores containing wolfram was still applicable until a very recent period, whe a new process was invented by Mr. Robert Oxland, of Plymouth, and by him successfully introduced at the Drake Walls Tin Mine, at Gunnis Lake, on the banks of the Tamar, where it was continued in operation until the mine was closed. At this mine, although the tin ore raised was of excellent quality, it was left associated with so much wolfram that the ore fetched the lowest price of any mine in Cornwall. By Oxland's process, it was brought up to the price of the best black tin. The process is now employed at East Huel Rose, near Camborne.

At the time of the introduction of the process the greater portion of the ore was sold for 42*l.* per ton. The improvement effected by it was so great that the same sort of ore fetched the price of the best black tin.

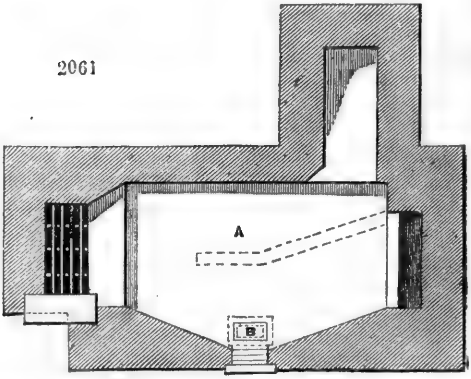
The process consists in taking tin ores mixed with wolfram, dressed as completely as possible by the old process, and having ascertained by analysis the quantity of wolfram contained therein, then mixing therewith such a quantity of soda-ash of known value as shall afford an equivalent of soda for combination with the tungstic acid of the wolfram, which is the tungstate of iron and manganese; the object of the process being by calcination to convert the insoluble tungstate of iron and manganese into the soluble tungstate of soda, leaving the oxides of iron and manganese in a very finely-divided state of low specific gravities, so that they can be easily washed off with water.

The mixture, in charges of five to ten cwts., is roasted in a reverberatory furnace on a cast-iron bed of the construction shown in the annexed engraving. The use of the cast-iron bed is attended with considerable economy in the consumption of fuel, and it is admirably well adapted for the calcination of the raw ores, for the evolution of the sulphur and arsenic contained in them, but it is especially necessary, instead of fire-brick or tile, to avoid the loss which would accrue from the reaction of the soda-ash on the silica of the brick, and the formation of soda silicate of tin which would consequently take place. The mixture is introduced to the bed through a hole in the crown of the furnace; from a side door it is equally distributed over the bed, and from time to time it is turned over by the furnaceman until the whole mass is of a dull red heat, emitting a slight hissing sound, and in an incipient pasty condition. In successive quantities the charge is then drawn through a hole in the bed of the furnace into the *wrinkle* or arch beneath, whence it is removed to cisterns, in which it is lixiviated with water, and the tungstate of soda is drawn off in solution. The residuary mass left in the cisterns,—the whole of the soluble matter having been washed out,—is removed to the burning-house floors, and is there dressed over again in the usual manner, the final product of the operations being very nearly pure black oxide of tin. The liquid obtained is either evaporated sufficiently for crystallisation when set aside to cool, or is at once dried down to powder. The crystals of tungstate of soda thus obtained are colourless, translucent, of a beautiful pearly lustre, having the form of rhombic prisms or of four-sided laminæ.

2060



2061



It has been proposed to use this substance as a mordant for dyeing purposes, as a source of supply of metallic tungsten for the manufacture of alloys, for the manufacture of the tungstates of lime, baryta, and of lead to be used as pigments; and still more recently it has been found to be preferable to any other substance, for rendering fabrics non-inflammable, so as to prevent the terrible accidents constantly occurring from the burning of ladies' dresses. For this purpose a patent was obtained by Messrs. Versmann and Oppenheim.

For the manufacture of metallic alloys a patent has been obtained by Mr. R. Oxland, as a communication from Messrs. Jacob and Koeller. It is prepared by simply melting with cast steel, or even with iron only, either metallic tungsten, or preferably, what has been termed the 'native alloy,' of tungsten, in the proportion of two to five per cent. The steel obtained works exceedingly well under the hammer. It is very hard and fine grained, and for tenacity and density is superior to any other steel made. The 'native alloy,' is obtained by exposing to strong heat in a charcoal-lined crucible a mixture of clean powdered wolfram with fine carbonaceous matter. A black steel-grey metallic spongy mass is obtained resembling metallic tungsten.

The tungstate of soda is used in dyeing. Metallic tungsten is also used for the manufacture of packfong or Britannia metal, by alloying with copper and tin.

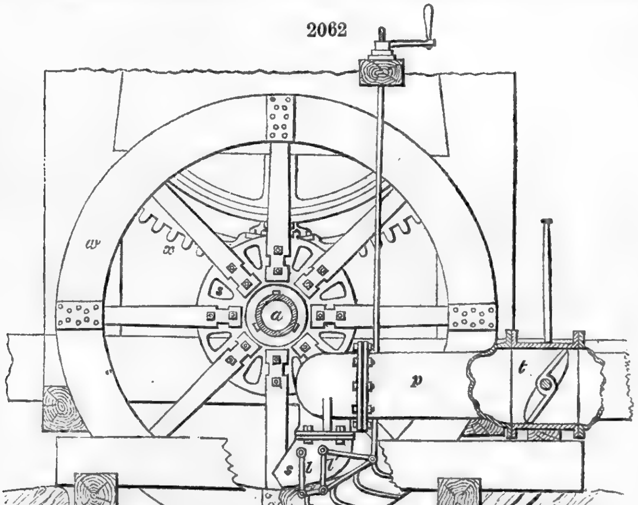
TURBA. This is a mere local word used in the want of knowledge of a more precise designation. *Turba*, in Portuguese and Spanish (like *Tourbe* in French), is

Tourbe in French), is a general term signifying any peat-like or earthy deposit formed in swamps and afterwards dried, and is also applied to peat itself.

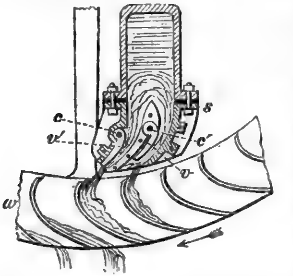
TURBINE. Numberless are the varieties, both of principle and of construction, to be met with in the mechanisms by which motive power may be obtained from falls of water. The chief modes of action of the water are, however, reducible to three, as follow:—First: The water may act directly, by its weight, on a part of the mechanism which descends while loaded with water, and ascends while free from load. The most prominent example of the application of this mode is afforded by the ordinary bucket water-wheel. Second: The water may act by fluid pressure, and drive before in some part of the vessel, by which it is confined. This is the mode in which the water acts in the water-pressure-engine, analogous to the ordinary high-pressure steam-engine. Third: The water, having been brought to its place of action, subject to the pressure due to the height of its fall, may be allowed to issue through small orifices with a high velocity, its inertia being one of the forces essentially involved in the communication of the power to the mechanism. Throughout the general class of wheels called Turbines, which is of wide extent, the water acts according to some of the variations of which this third mode is susceptible. The name Turbine is derived from the Latin word *turbo*, 'a top,' because the wheels to which it is applied almost all spin round a vertical axis, and so bear some considerable resemblance to the top. In our own country, and more especially on the Continent, turbines have attracted much attention, and many forms of them have been made known by published descriptions.

Turbines for Mining Purposes.—Although the horizontal water-wheel has been known and employed under various forms from the highest antiquity, and has latterly been improved by Fourneyron, Fontaine, Jouval, and others, so as to rank among the most perfect of hydraulic motors, it has only recently been applied to mining uses (pumping, loading, &c.), and where so employed its success can scarcely be said to be yet decided. The failures may be attributed to the following causes:—First: The plan of causing the water to flow simultaneously through all the buckets necessitates the use of wheels of small dimensions, making a very great number of revolutions per minute, and thus requiring a considerable train of intermediate gear to reduce the speed to the working rate. Second: The complex nature of the ring sluices employed between the guide curves and the mouths of the buckets, renders them uncertain in action, and from their small dimensions liable to be easily choked by any

2062



mechanical impurities in the water; and lastly, the lubrication of the foot spindle of the vertical wheel, revolving at very great velocity, is attended with considerable difficulty and inconvenience, especially where the engine-room is at a considerable distance below the surface of the earth, and it is requisite, as in the case of pumping wheels, to keep the machinery in action continuously for long periods of time. The form of wheel of which a notice is here appended, was introduced into the Saxon mines about the year 1849 by Herr Schwamkrug, inspector of machinery at the Royal Mines and Smelting Works at Freiberg, and since that time several have been introduced for pumping, winding, driving stamp-heads, &c. The example selected for illustration was built to take the place of two overshot water-wheels, employed in pumping water at the mine 'Churprinz Friedrich August': it differs from the usual form of turbine in having the wheel placed vertically, and in having the water supplied through a small number of guide-curves near the lowest part. In this latter respect it resembles the tangential turbine of General Poncelet, with this difference that the water flows from the inner to the outer circumference, instead of the reverse way, as is the case in Poncelet's wheel. The construction of the wheel is as follows: *a*, *fig.* 2062, is the tubular axle of cast iron which carries the seating for the arms, *s*, which is similar to that usually used for large water-wheels; to the ends of the arms is attached the wheel *w*, which is formed of two brags or shroudings of sheet iron, each 13 inches deep, measured radially, and of a total height of 10 feet 2 inches; these two rings are maintained at a distance of 6 inches apart, by means of 44 sheet-iron buckets of the form shown in the smaller detailed figure, *fig.* 2063; the driving water is admitted through the pressure pipe, *p*, in which is placed the admission throttle, *t*, and turned through a pipe of rectangular section (shown in the smaller figure) into the sluice box, *s*, which contains the two guide-curves, *v*, *v'*, which are moveable about the centres, *c*, *c'*, by means of the levers, *l*, *l'*; by means of these guide-curves when fully opened, as shown in the figure, the water is admitted into the buckets in two parallel streams or jets of 5$\frac{3}{4}$ inches in breadth, and 1$\frac{3}{10}$ths in. in thickness; the power is transmitted from the axle of the wheel by a pinion with 28 teeth, which draws the large toothed wheel, *x*, which acts on a third shaft carrying the pump-cranks. The wheel is constructed to work under a head of 147 feet, and makes about 130 revolutions per minute, with a maximum quantity of 550 cubic feet of water, equal to nearly 175 horse-power. A series of dynamometrical experiments on a wheel of similar construction of 7 feet 9 inches in diameter, with a discharge varying from 39 to 134 cubic feet, with a head of 103 feet, gave an available duty of from 58 to 70 per cent., the number of revolutions varying from 112 to 148 per minute.



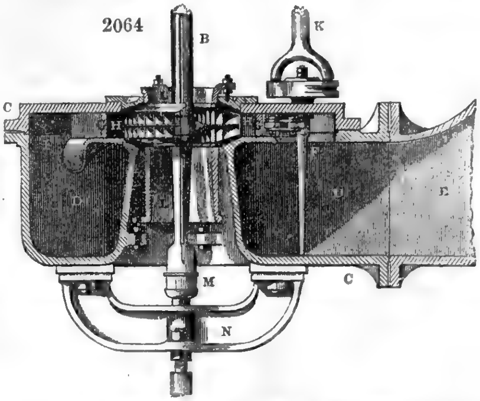
In conclusion, it may be remarked that the vertical turbine may be employed with advantage where the available fall of water is too great to be employed on a single overshot water-wheel; and although a less perfect machine than the water-pressure engine, it is of simpler construction, and may be preferred where, from the hardness or yielding nature of the rock, it becomes difficult to construct large machine-rooms or wheel-pits underground. In practice it is found necessary to surround the wheel with a casing of wood, in order to prevent the affluent water from being projected to a distance by centrifugal action.

A fine model of one of these turbines, with two sets of buckets, constructed for the purpose of winding (*Turbinengöpel*), may be seen at the Museum of Practical Geology, Jermyn Street.

For further information on this subject, we may refer to the *Polytechnisches Centralblatt*, Nos. 8, 9, for 1845, and No. 3 for 1850; to the *Jahrbuch für den Berg- und Hüttenmann*, for 1850 and 1853. The subject of turbines is treated in great detail in Weisbach's 'Mechanics of Machinery and Engineering.' Redlenbache's *Theorie und Bau der Turbinen und Ventilatoren*, Mannheim, 1844, is the best and most complete work on the subject. Notices of Fourneyron's, Jouval's, and Fontaine's turbines are to be found in Glyn's 'Rudimentary Treatise on Water-Power,' in Weale's Series. The original notice of Fourneyron's turbine is published in the *Bulletin de la Société d'Encouragement*, for 1834, and several new forms are noticed in the various volumes of Armengaud's *Publication Industrielle.*

The name of Vortex Wheel has been given to a modification of the turbine by Mr. James Thomson of Belfast. In this machine the moving wheel is placed within a chamber of a nearly circular form. The water is injected into the chamber tangentially at the circumference, and thus it receives a rapid motion of rotation. Retaining this motion, it passes towards the centre, where alone it is free to make its exit. The wheel, which is placed within the chamber, and which almost entirely fills it, is divided by thin partitions into a great number of radiating passages. Through these passages the water must flow in its course towards the centre; and, in doing so, it imparts its own rotatory motion to the wheel. The whirlpool of water, acting within the wheel-chamber, being one principal feature of this turbine, leads to the name *Vortex*, as a suitable designation for the machine as a whole.

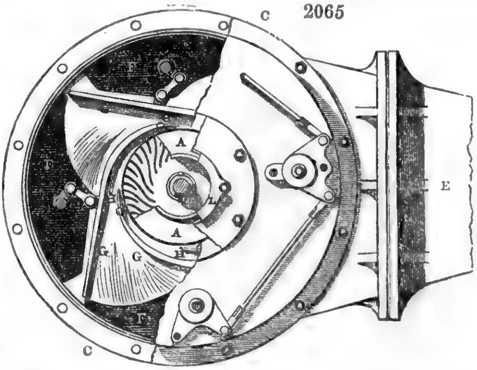
2064



The vortex admits of several modes of construction; but the two principal forms are the one adapted for high falls, and the one for low falls. The former may be called the high-pressure vortex, and the latter the low-pressure vortex. An example of each of these two kinds is delineated in the accompanying figures.

Figs. 2064 and 2065 are respectively a vertical section and a plan of a vortex constructed for employing a very high fall near Belfast to drive a flax-mill.[1] A A is the water-wheel. It is fixed on the upright shaft B, which conveys away the power to the machinery to be driven. The water-wheel occupies the central part of the upper division of a strong cast-iron case C C. This part of the case is called the *wheel-chamber*. D D is the lower division of the case, and is called the *supply-chamber*. It receives the water directly from the supply pipe, of which the lower extremity is shown at E, and delivers it into the outer part of the upper division by four large openings F, in the partition between the two divisions. This outer part of the upper division is called the *guide-blade chamber*, from its containing four guide-blades, G, which direct the water tangentially into the wheel-chamber. Immediately after being injected into the wheel-chamber, the water is received by the curved radiating passages of the wheel, which are partly to be seen in *fig.* 2065, at a place where both the cover of the wheel-chamber and the upper plate of the wheel are broken away for the purpose of exposing the interior to view. The water on reaching the inner ends of these curved passages, having already done its work, is allowed to make its exit by two large central orifices, shown distinctly on the figures at or adjacent to the letters L L, the one leading upwards and the other downwards. Close joints between the case and the wheel, to hinder the escape of water otherwise than through the radiating passages, are made by means of two annular pieces L, L, called *joint-rings*, fitting to the central orifices of the case, and capable of being adjusted, by means of studs and nuts, so as to come close to the wheel without impeding its motion by friction. The four openings H, H, *fig.* 2065, through which the water flows into the wheel-chamber, each situated between the point or edge of one guide-blade and the middle of the next, determine, by their width, the quantity of water admitted, and consequently the power of the wheel. To render this power capable of being varied at pleasure, the guide-blades are made moveable round gudgeons or centres near their points; and a spindle K, worked by a handle in any convenient position, is connected

2065



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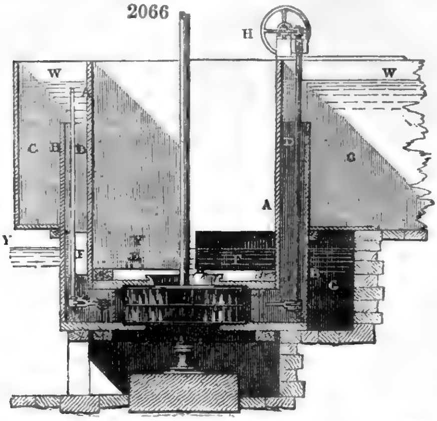
[1] In these figures, as also in *figs.* 2066, 2067, some unimportant modifications are made for the purpose of simplifying the drawings, and rendering them more easily understood than they would otherwise be.

with the guide-blades by means of links, cranks, &c. (see the figures), in such a way that when the handle is moved, the four entrance orifices are all enlarged or contracted alike. The gudgeons of the guide-blades, seen in *fig.* 2064, as small circles near the points, are sunk in sockets in the floor and roof of the guide-blade chamber, and so they do not in any way obstruct the flow of the water. M is the pivot-box of the upright shaft, and is constructed with peculiar provisions for oiling the pivot, which, by reason of its being under water, does not admit of being oiled by ordinary means. N is a hanging bridge which forms the mixture of the pivot.

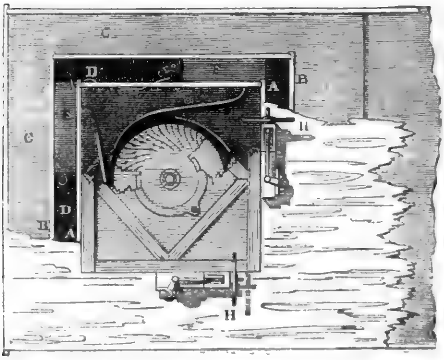
This vortex is calculated for 50 horse-power, with a fall varying from 90 to 100 feet. On account of the great height of the fall, the machine comes to be of very small dimensions; the diameter of the water-wheel itself being only about 15 inches, and he extreme diameter of the case 3 feet 9 inches. The speed for which the wheel is calculated, in accordance with its diameter and the velocity of the water entering its chamber, is 768 revolutions per minute.

2066



A low-pressure vortex constructed for another mill near Belfast, is represented, in vertical section and plan, in *figs.* 2066 and 2067. This is essentially the same in principle as the vortex already described, but it differs in the material of which the case is constructed, and in the manner in which the water is led to the guide-blade chamber. In this the case is almost entirely composed of wood. The water flows with a free upper surface W W, into this wooden case, which consists chiefly of two tanks A A, and B B, one within the other. The water-wheel chamber, and the guide-blade chamber, are situated in the open space between the bottom of the outer and that of the inner tank, and will be readily distinguished by reference to the figures. The water of the head race having been led all round the outer tank in the space, C C, flows inwards over its edge, and passes downwards by the space D D, between the sides of the two tanks. It then passes through the guide-blade chamber and the water-wheel, just in the same way as was explained in respect to the high-pressure vortex already described; and in this one likewise it makes its exit by two central orifices, the one discharging upwards and the other downwards. The part of the water which passes downwards flows away at once to the tail race, and that which passes upwards into the space E, within the innermost tank, finds a free escape to the tail race through boxes and other channels, F and G, provided for that purpose. The wheel is completely submerged under the surface of the water in the tail race, which is represented at its ordinary level at Y Y, *fig.* 2066, although in floods it may rise to a much greater height. The power of the wheel is regulated in a similar manner to that already described, in reference to the high-pressure vortex. In this case, however, as will be seen by the figures, the guide-blades are not linked together, but each is provided with a hand-wheel H, by which motion is communicated to itself alone.

2067



The foregoing descriptions are sufficient to explain the principal points in the structural arrangements of these water-wheels.

And now a few words more in respect to their principles may be added. In these machines the velocity of the circumference of the wheel is made the same as the velocity of the entering water, and thus there is no impact between the water and the wheel; but, on the contrary, the water enters the radiating conduits of the wheel gently, that is to say, with scarcely any motion in relation to their mouths. In order to attain the equalisation of these velocities, it is necessary that the circumference of the wheel should move with the velocity which a heavy body would attain in falling through a vertical space equal to half the vertical fall of the water, or, in other words, with the velocity *due* to half the fall; and that the orifices through which the water is injected into the wheel-chamber should be conjointly of such an area, that, when all the water required is flowing through them, it also may have the velocity due to half the fall.

Thus one half only of the fall is employed in producing velocity in the water; and, therefore, the other half still remains, acting on the water within the wheel-chamber at the circumference of the wheel, in the condition of fluid pressure. Now, with the velocity already assigned to the wheel, it is found that this fluid pressure is exactly that which is requisite to overcome the centrifugal force of the water in the wheel, and to bring the water to a state of rest at its exit, the mechanical work due to both halves of the fall being transferred to the wheel during the combined action of the moving water and the moving wheel. In the foregoing statements, the effects of fluid friction, and of some other modifying influences, are, for simplicity, left out of consideration.

TURBITH'S MINERAL or **TURPETH MINERAL.** The yellow sub-sulphate of mercury, called Queen's Yellow.

TURF (*Peat*, Scotch; *Tourbe*, Fr.; *Torf*, Ger.) consists of vegetable-matter, chiefly of the Moss family, in a state of partial decomposition by the action of water. Cut, during summer, into brick-shaped pieces, and dried, it is extensively used as fuel by the peasantry in every region where it abounds. The dense black turf, which forms the lower stratum of a peat moss, is much contaminated with iron, sulphur, sand, &c., while the lighter turf of the upper strata, though nearly pure vegetable-matter, is too bulky for transportation, and too porous for factory fuel. These defects have been removed, several processes having been patented for converting the lightest and poorest beds of peat-moss, or bog, into the four following products: 1. A brown combustible solid, denser than oak; 2. A charcoal, twice as compact as that of hard wood; 3. A factitious coal; and 4. A factitious coke: each of which possesses very valuable properties.

Mr. D'Ernst, artificer of fireworks to Vauxhall, proved, by the severe test of coloured fires, that turf-charcoal is 20 per cent. more combustible than that of oak. Mr. Oldham, engineer of the Bank of England, applied it in softening his steel plates and dies, with remarkable success. A prospect was thus opened up of turning to admirable account the unprofitable bogs of Ireland; and of producing, from their inexhaustible stores, a superior fuel for every purpose of arts and engineering.

The turf is treated as follows:—Immediately after being dug, it is triturated under revolving edge-wheels, faced with iron plates perforated all over their surface, and is forced by the pressure through these apertures, till it becomes a species of pap, which is freed from the greater part of its moisture by squeezing in a hydraulic press between layers of caya-cloth; then dried, and coked in suitable ovens. (See CHARCOAL, and COKE.) Mr. Williams, by his patent, makes his factitious coal by incorporating with pitch or resin, melted in a cauldron, as much of the above charcoal, ground to powder, as will form a doughy mass, which is moulded into bricks in its hot and plastic state. It has been found preferable to all other fuel for case-hardening iron, tempering steel, forging horse-shoes, and welding gun-barrels. Since turf is partially carbonised in its native state, when it is condensed by the hydraulic press, and fully charred, it affords a charcoal superior in calorific power to the porous substance obtained from wood. For recent modes of utilising peat, see PEAT.

TURKEY RED is the name given to one of the most beautiful and durable of known dyes. The art of dyeing cotton with this colour seems to have originated in India. In his 'Philosophy of Permanent Colours,' Bancroft has given a detailed account of the process as practised in that country; and this process will be found to agree in all essential particulars with that pursued by the Turkey-red dyers of Europe, except that in India the chaya-root is employed as the dyeing material in the place of madder. In the middle ages the art was practised in various parts of Turkey and Greece, especially in the neighbourhood of Adrianople, and hence this colour is often called *Adrianople Red.* Even as late as the end of last century the manufacture of Turkey-red yarn seems to have been extensively carried on at Ambelakia and other places in the neighbourhood of Larissa. An interesting account of the manufactures and trade of this then flourishing district, by Felix, will be found in the *Annales de Chimie*, t. xxi. 1799. About the middle of last century the art of Turkey-red dyeing was introduced into France by means of dyers brought over from Greece. The

French were also the first to dye pieces with this colour, the art having previously been applied merely to the dyeing of yarn. The first establishments for dyeing this colour in Great Britain were founded and conducted by Frenchmen. At the present day Turkey-red dyeing is carried on in various parts of France and Switzerland, at Elberfeld in Germany, in Lancashire, and at Glasgow.

Turkey-red dyeing is essentially distinguished from other dyeing processes by the application previous to dyeing of a peculiar preparation consisting of fatty matter combined with other materials. Without the use of oil or some fatty matter it would be impossible to produce this colour, of which indeed it seems to form an essential constituent. If the colour of a piece of Turkey-red cloth be examined in the manner described under **Madder**, it will be found to consist of red colouring-matter and fat-acid, combined with alumina and a little lime. The colouring-matter thus obtained is so little contaminated with impurities as to appear on evaporating its alcoholic solution in yellowish-red crystalline needles. What part the fat-acid plays, whether it merely serves to give to the compound of colouring-matter and alumina the power of resisting the action of the powerful agents used after the operation of dyeing, or whether it also modifies and imparts additional lustre to the colour itself, is quite unknown. The formation of this triple compound of colouring-matter, fat-acid, and alumina, seems at all events to be the final result which is attained. Nevertheless, this apparently simple result can only be arrived at by means of a long and complicated process, each step of which seems to be essential for its final success. The details of the process vary considerably both in their nature and number, in different countries and different dyeing establishments. They may, however, be described in general terms as follow:—

The goods, after being passed through a soap-bath or weak alkaline lye, are oiled. For this purpose a mere impregnation with oil would not be sufficient. The oil must be mixed with a solution of carbonate of potash or soda, to which there is often added a quantity of sheep- or cow-dung, the ingredients being well mingled, so as to form a milky liquid or emulsion. Olive or Gallipoli oil is the kind generally used, and an impure, mucilaginous oil is preferred to one of a finer quality. Drying oils are not adapted for the purpose. In this liquid the goods are steeped for a short time, so as to become thoroughly impregnated with it. In the case of pieces the liquid is generally applied by means of a padding machine. After being taken out of this liquid the goods are often left to lie for some days in heaps, and if the weather is fine, they are then exposed on the grass to the action of the air; otherwise, they must be hung up in a hot stove. This process of steeping and exposing to the air is repeated a number of times, until the fabric is thoroughly impregnated with fatty matter. During this part of the process there can be no doubt that the oil undergoes a partial decomposition and oxidation, so as to become capable of uniting, on the one hand, with the vegetable fibre, and, on the other hand, with the colouring-matter, with which it is subsequently brought into contact. The dung, by inducing a state of fermentation among the ingredients probably promotes the decomposition of the oil into fatty acid and glycerine, and the alkali serves to convey the fatty acid into every part of the fabric, and to assist in its oxidation on exposure to the air. The process of oxidation which takes place is sometimes so active as to produce spontaneous combustion of the goods in the stove. It might be supposed that by previously saponifying the oil, impregnating the goods with the soap, and after sufficient exposure, decomposing the latter by means of an acid, the same object might be more easily attained than by the long process usually employed. This is, however, not the case, which proves that we are still ignorant of the exact chemical nature of the change which takes place during the oiling process. The supposition formerly entertained, that the effect of the oiling consisted in a so-called *animalisation* of the vegetable fibre, is quite untenable. In some establishments, the goods, after being oiled and stoved, are passed through a bath of very dilute nitric acid, and then exposed to the air before being oiled again, the process being repeated after every oiling. The nitric acid is supposed to contribute to the oxidation of the oil. Several years ago a patent was taken out by Messrs. Mercer and Greenwood for preparing the oil, previous to its being applied to the cotton, by treating it with sulphuric acid, and then with chloride of soda, but their invention, though apparently of some importance, has not generally been adopted by Turkey-red dyers.

After being oiled, the goods are steeped for some hours in a weak tepid solution of carbonate of potash or soda. This operation, which is called by the French *dégraissage*, serves to remove the excess of fatty acid, or that portion which has not thoroughly combined with the vegetable fibre. The liquid thus obtained is carefully preserved for the purpose of being mixed with the liquid used for the oiling of fresh goods, the quality of which it serves to improve.

To this operation succeeds that of galling and mordanting. The goods, after being washed, are passed through a warm solution of tannin, prepared by extracting galls or sumac with boiling water and straining, after which they are impregnated with a solution of alum, to which sometimes a little chalk or carbonate of potash is added, or with a solution of acetate of alumina, prepared by double decomposition from alum and acetate of lead. Sometimes the alum is dissolved in the decoction of galls, and thus the two operations are combined into one. The goods, after being dried in the stove, passed through hot water containing chalk, and rinsed, are now ready to be dyed. It has been asserted that the galling is not an essential part of the process, that it merely serves to fix the alumina of the mordant, and may be dispensed with when acetate of alumina is used instead of alum. It is certainly difficult to conceive how it can permanently affect the appearance of the colour, since the tannin of the galls is undoubtedly removed from the fibre during the subsequent stages of the process.

The dyeing is performed in the usual manner. (See MADDER and CALICO-PRINTING.) The materials employed are madder, chalk, sumac, and blood, in various relative proportions. The heat of the dye-bath is gradually raised to the boiling point, and the boiling is continued for some time. The part played by the chalk in dyeing with madder has been explained elsewhere. (See MADDER.) It was formerly supposed that the red colouring-matter of the blood contributed in producing the desired effect in Turkey-red dyeing; but to the modern chemist this supposition does not appear probable. Nevertheless, it is certain that the addition of blood is of some benefit, though it is uncertain in what the precise effect consists. Glue is occasionally employed in the place of blood. Sometimes a second mordanting with galls and alum, and a second dyeing, is allowed to succeed the first mordanting and dyeing.

After being dyed the goods appear of a dull brownish-red colour, and they must therefore be subjected to the brightening process, in order to make them assume the bright red tint required. For this purpose they are first treated with a boiling solution of soap and carbonate of potash or carbonate of soda, and then with a mixture of soap and muriate-of-tin crystals. This operation is usually performed in a close vessel under pressure. The alkalis remove the brown colouring-matters and the excess of fat-acid contained in the colour, and the tin salt probably acts by extracting a portion of the alumina of the mordant, and substituting in its place a quantity of oxide of tin, which has the effect of giving the colour a more fiery tint. The last finish is given to the colour by treating the goods with bran or with chloride of soda.

The chief objects which the Turkey-red dyer seeks to attain are, 1st, to obtain the desired effect with the least possible expenditure of time and material; 2nd, to produce a perfect uniformity of tint in the same series of dyeings; and 3rd, to impart to his goods a colour which, though perfectly durable, shall be fixed as much as possible on the surface of the fabric. The last point is one of importance in the case of calicoes dyed of this colour, since this kind of goods is much employed for the production of a peculiar style of prints, in which portions of the colour are discharged, in order either to remain white or to be covered with other colours. (See CALICO-PRINTING.) And if the red dye is too firmly fixed, or too deeply seated, it becomes more difficult to discharge it. In this respect the art has in modern times attained to such a degree of perfection, that the interior of each thread of Turkey-red cotton will be found on examination to be perfectly white. This is particularly the case with the Turkey-reds from the establishment of Mr. Steiner, Accrington, Lancashire, whose productions in this branch of the art of dyeing are also unrivalled for the brilliancy and purity of their colour.—E. S.

TURMERIC (*Curcuma*, *Terra merita*, *Souchet* or *Safran des Indes*, Fr.; *Gelbwurzel*, Ger.) is the rhizome of the *Curcuma longa* and *C. rotunda*, a plant which grows in the East Indies, where it is much employed in dyeing yellow, as also as a condiment in curry sauce or powder. The root is knotty, tubercular, oblong, and wrinkled; pale-yellow without, and brown-yellow within; of a peculiar smell, a taste bitterish and somewhat spicy. It contains a peculiar yellow principle, called *Curcumine*, a brown colouring-matter, a volatile oil, starch, &c. The yellow tint of turmeric is changed to brown-red by alkalis, alkaline earths, subacetate of lead, and several metallic oxides; for which reason, paper stained with it is employed as a chemical test.

Turmeric is employed by the wool-dyers for compound colours which require an admixture of yellow, as for cheap browns and olives. As a yellow dye it is employed only upon silk. It is a very fugitive colour. A yellow-lake may be made by boiling turmeric-powder with a solution of alum, and pouring the filtered decoction upon pounded chalk.

TURNBULL'S BLUE. Ferricyanide of iron, obtained by precipitating a solution of a salt of protoxide of iron with ferricyanide of potassium. See BLUE PIGMENTS and PRUSSIAN BLUE.

TURNER'S YELLOW. An oxychloride of lead. See PATENT YELLOW.

TURNSOLE. See ARCHIL and LITMUS.

TURPENTINE. (*Térébenthine*, Fr.; *Terpentin*, Ger.) The term *Turpentine* is applied to a liquid or soft solid product of certain coniferous plants, and of the *Pistachia Terebinthus.*

The following varieties are those which are usually found in the market:—American or White Turpentine; Bordeaux Turpentine; Venice Turpentine; Strasburg Turpentine; Canadian Turpentine, or Canada Balsam; Chio Turpentine; Frankincense.

In nearly all cases the processes of collecting are similar. A hollow is cut in the tree yielding the turpentine, a few inches from the ground, and the bark removed for the space of about 18 inches above it. The turpentine runs into this hollow for several months, especially during the summer months. In general character these turpentines have much in common; being oleo-resins, varying slightly in colour, consistency, and smell. They enter into the composition of many varnishes.

TURPENTINE, OIL OF. This is obtained by distilling American turpentine (which has been melted and strained) with water in an ordinary copper still. The distilled product is colourless, limpid, very fluid, and possessed of a peculiar smell. Its specific gravity, when pure, is 0·870; that of the oil commonly sold in London is 0·875. It always reddens litmus-paper, from containing a little succinic acid. According to Oppermann, the oil which has been repeatedly rectified over chloride of calcium, consists of 84·60 carbon, 11·735 hydrogen, and 3·67 oxygen. Rectified oil of turpentine is known as spirits or essence of turpentine. When oil of turpentine contains a little alcohol, it burns with a clear flame; but otherwise it affords a very smoky flame. (See CAMPHINE.) Chlorine inflames this oil; and hydrochloric acid converts it into a crystalline substance, like camphor. It is employed extensively in varnishes, paints, &c., as also in medicine.

TURQUOISE. This gem is a compound of phosphate of alumina, with oxide of copper. The Silesian turquoise, according to John, consists of:—alumina, 44·50; phosphoric acid, 30·90; water, 19·00; oxide of copper, 3·75; oxide of iron, 1·80: while the blue Oriental turquoise was found by Hermann to consist of alumina, 47·45; phosphoric acid, 27·34; water, 18·18; oxide of copper, 2·02; oxide of iron, 1·10; manganese, 0·50; and phosphate of lime, 3·41.

Turquoise occurs in the mountainous ranges of Persia, and when finely coloured it is highly esteemed as a gem. The Shah of Persia is said to retain for his own use all the more remarkable specimens. It is also found in Thibet.

Major Macdonald discovered a new locality for the turquoise in Arabia Petræa. Of the discovery of these, he gives the following account:—

'In the year 1849, during my travels in Arabia in search of antiquities, I was led to examine a very lofty range of mountains composed of iron sandstone, many days' journey in the desert, and whilst descending a mountain of about 6,000 feet high by a deep and precipitate gorge, which in the winter time served to carry off the water, I found a bed of gravel, where I perceived a great many small blue objects mixed with the other stones; on collecting them I found they were turquoises of the finest colour and quality. On continuing my researches through the entire range of mountains, I discovered many valuable deposits of the same stones, some quite pure, like pebbles, and others in the matrix. Sometimes they are found in nodules varying in size from a pin's head to a hazel-nut; and when in this formation they are usually of the finest quality and colour. The action of the weather gradually loosens them from the rock, and they are rolled into the ravines, and, in the winter season, mixed up by the torrents with beds of gravel, where they are found. Another formation is, where they appear in veins, and sometimes of such a size as to be of immense value. They also occur in a soft yellow sandstone, enclosed in the centre, and of a surpassing brilliancy of colour. Another very curious formation is where they are combined with innumerable small coloured quartz crystals, and which has the appearance of a mass of sand, small pebbles, and turquoise, all firmly cemented together. This formation is one of the most peculiar in the whole collection.'

Mr. Harry Emanuel, speaking of the Persian turquoise, says that, 'small clear stones bring from 6*d.* to 20*s.* each, whilst fine ring-stones will realise from 10*l.* to 40*l.*' . . . 'A perfect stone of the size of a shilling, and of good depth, was sold not long ago for 400*l.*' 'A good turquoise, sky blue and oval cut, five lines long and four and a half lines broad, was sold in France for 241 francs; and a light blue, greenish lustre, and oval cut, five and a half lines long and five broad, was sold for 500 francs; whereas an occidental turquoise, four lines long and three and a half broad, brought only 121 francs.'—*Feuchtwanger.*

The occidental turquoise, frequently called the 'bone turquoise,' or *Odontolite*, is said to be fossil bone, ivory, or teeth, coloured with phosphate of iron.

Turquoise is imitated by adding to the ammonia sulphate of copper, or oxide of copper dissolved in ammonia, finely-powdered calcined ivory. They are allowed to remain together for about a week, at a moderate heat. The coherent mass is dried and exposed to a gentle heat.

TUSSILAGO. The herb Coltsfoot (*Tussilago farfara*).

TUTENAG or **TUTENAGUE,** sometimes called *Chinese silver*. It is the *Packfong* of the East Indies. A white metal of the Chinese, frequently stated to be an alloy of copper and zinc. It is, in fact, a compound resembling German silver: nickel, in combination with zinc and copper, is found in most specimens

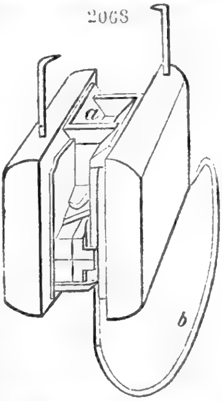
TUTONITE. See Explosive Agents.

TYMP, in *metallurgy*, a rectangular casting of iron, placed upon the tymp-arch at the top of the hearth of a blast-furnace. When it has a wrought-iron tube in its interior through which cold water circulates, it is then called a 'water-tymp.'

TYPE. (*Caractère*, Fr.; *Druckbuchstabe*, Ger.) The first care of the letter-cutter is to prepare well-tempered steel punches, upon which he draws or marks the exact shape of the letter, with pen and ink if it be large, but with a smooth blunted point of a needle if it be small; and then, with a proper sized and shaped graver and sculpter, he digs or scoops out the metal between the strokes upon the face of the punch, leaving the marks untouched and prominent. He next works the outside with files, till it be fit for the matrix. Punches are also made by hammering down the hollows, filing up the edges, and then hardening the soft steel. Before he proceeds to sink and justify the matrix, he provides a mould to justify them by.

A matrix is a piece of brass or copper, about an inch and a half long, and thick in proportion to the size of the letter which it is to contain. In this metal the face of the letter intended to be cast is sunk, by striking it with the punch to a depth of about one-eighth of an inch. The mould, *fig.* 2068, in which the types are cast, is composed of two parts. The outer part is made of wood, the inner of steel. At the top it has a hopper-mouth, *a*, into which the fused type-metal is poured. The interior cavity is as uniform as if it had been hollowed out of a single piece of steel; because each half, which forms two of the four sides of the letter, is exactly fitted to the other. The matrix is placed at the bottom of the mould, directly under the centre of the orifice, and is held in its position by a spring, *b*. Every letter that is cast can be loosened from the matrix only by removing the pressure on the spring.

2068



A good type-foundry is always provided with several furnaces, each surmounted with an iron pot containing the melted alloy, of 3 parts of lead and 1 of antimony. Into this pot the founder dips the very small iron ladle, to lift merely as much metal as will cast a single letter at a time. Having poured in the metal with his right hand, and returned the ladle to the melting-pot, the founder throws up his left hand, which holds the mould, above his head, with a sudden jerk, supporting it with his right hand. It is this movement which forces the metal into all the interstices of the matrix; for without it, the metal, especially in the smaller moulds, would not be able to expel the air and reach the bottom. The pouring in the metal, the throwing up the mould, the unclosing it, removing the pressure of the spring, picking out the cast letter, closing the mould again, and reapplying the spring to be ready for a new operation, are all performed with such astonishing rapidity and precision, that a skilful workman will turn out 500 good letters in an hour, being at the rate of one every eighth part of a minute. A considerable piece of metal remains attached to the end of the type as it quits the mould. There are nicks upon the lower edge of the types, to enable the compositor to place them upright without looking at them.

From the table of the *caster* the heap of types turned out of his mould is transferred from time to time to another table, by a boy, whose business it is to break off the superfluous metal, and this he does so rapidly as to clear from 2,000 to 5 000 types in an hour; a very remarkable despatch, since he must seize them by their edges, and not by their feeble flat sides. From the breaking-off boy the types are taken to the *rubber*, a man who sits in the centre of the workshop with a grit-stone slab on a table before him, and having on the fore and middle finger of his right hand a piece of tarred leather, passes each broad side of the type smartly over the stone, turning it in the movement, and that so dexterously as to be able to rub 2,000 types in an hour.

From the rubber the types are conveyed to a boy, who with equal rapidity sets them up in lines, in a long shallow frame, with their faces uppermost and nicks outwards. This frame containing a full line is put into the dresser's hands, who polishes them on each side, and turning them with their faces downwards, cuts a groove or channel in their bottom, to make them stand steadily on end. It is essential that each letter be perfectly symmetrical and square: the least inequality of their length would prevent them from making a fair impression; and were there the least obliquity in their sides, it would be quite impossible, when 200,000 single letters are combined, as in one side of *The Times* newspaper, that they could hold together as they require to do, when wedged up in the chases, as securely as if that side of the type formed a solid plate of metal. Each letter is finally tied up in lines of convenient length, the proportionate numbers of each variety, small letters, points, large capitals, small capitals, and figures, being selected, when the fount of type is ready for delivery to the printer.

The sizes of types cast in this country vary, from the smallest, called Diamond, of which 205 lines are contained in a foot length, to those letters employed in placards, of which a single letter may be several inches high. The names of the different letters and their dimensions, or the number of lines which each occupies in a foot, are stated in the following table:—

Double Pica	41½	Small Pica	83	Minion	128
Paragon	44½	Long Primer	89	Nonpareil	143
Great Primer	51¼	Bourgeois	102¼	Pearl	178
English	64	Brevier	112½	Diamond	205
Pica	71½				

TYPE METAL. An alloy of 3 parts of lead and 1 of antimony. Small type, however, usually contains tin, in proportions varying from 1½ to 20 per cent.

TYRIAN PURPLE. A costly dye obtained from a mollusc, which was employed by the Tyrians in dyeing wool. See Crookes's 'Handbook of Dyeing.'

TYRITE. A Norwegian mineral, containing columbic acid and yttria, discovered and analysed by David Forbes.

TYROLINE. See Aniline Violet.

TYROLITE. An arsenate of copper found in the Tyrol.

TYROSINE. See Aniline.

U

ULEXITE. A native borate of lime and soda, known also as *Boronatrocalcite*. It occurs at Iquique, in Peru; and in the Province of Tarapaca. See Boron.

ULLMANNITE. An antimonio-sulphide of nickel, occasionally containing arsenic. It occurs at Freusberg, in Nassau.

ULTRAMARINE (*Outremer*, Fr.; *Ultramarin*, Ger.), is a beautiful blue pigment, obtained from the blue mineral called *lapis-lazuli*, by the following process:—Grind the stone to fragments, rejecting all the colourless bits, calcine at a red heat, quench in water, and then grind to an impalpable powder along with water, in a mill, or with a porphyry slab and muller. The paste being dried, is to be rubbed to powder, and passed through a silk sieve. 100 parts of it are to be mixed with 40 of resin, 20 of white wax, 25 of linseed oil, and 15 of Burgundy pitch, previously melted together. This resinous compound is to be poured hot into cold water; kneaded well first with two spatulas, then with the hands, and then formed into one or more small rolls. Some persons prescribe leaving these pieces in the water during fifteen days, and then kneading them in it, whereby they give out the blue pigment, apparently because the ultramarine matter adheres less strongly than the *gangue*, or merely siliceous matter of the mineral, to the resinous paste. MM. Clément and Desormes, who were the first to divine the true nature of this pigment, thought that the soda contained in the lapis-lazuli, uniting with the oil and the resin, forms a species of soap, which serves to wash out the colouring-matter. If it should not separate readily, water heated to about 150° Fahr. should be had recourse to. When the water is sufficiently charged with blue colour, it is poured off and replaced by fresh water; and the kneading and change of water are repeated till the whole of the colour is extracted. Others knead the mixed resinous mass under a slender stream of water, which runs off with the colour into a large earthen pan. The first waters afford, by rest, a deposit of the finest ultramarine; the second a somewhat inferior article, and so on. Each must be washed afterwards with several more waters before they acquire the highest quality of tone; then dried separately, and freed from any adhering particles of the pitchy compound by digestion in alcohol. The remainder of the mass being melted with oil and kneaded in water containing a little soda or potash, yields an inferior pigment, called *ultramarine ashes*. The best *ultramarine* is a splendid blue pigment, which works well with oil, and is not liable to change by time.

Analyses of lapis-lazuli ultramarine will be found in the following article.

ULTRAMARINE, ARTIFICIAL. For many years every attempt failed to make ultramarine artificially. At length, in 1828, M. Guimet resolved the problem, guided by the analysis of MM. Clément and Desormes, and by an observation of M. Tassaert, that a blue substance, like ultramarine was occasionally produced on the sandstone hearths of his reverberatory soda-furnaces. M. Gmelin, of Tübingen, published a prescription for making it; which consisted in enclosing carefully in a Hessian crucible a mixture of 2 parts of sulphur and 1 of dry carbonate of soda, heating them gradually to redness until the mass fuses, and then sprinkling into it by degrees another mixture, of silicate of soda and aluminate of soda; the first containing 72 parts of silica, and the second 70 parts of alumina. The crucible must be exposed after this for an hour to the fire. The ultramarine will be formed by this time; only it contains a little sulphur, which can be separated by means of water M. Persoz likewise succeeded in making an ultramarine, of perhaps still better quality than that of M. Guimet. Lastly, M. Robiquet has announced, that it is easy to form ultramarine by heating to redness a proper mixture of kaolin (China clay), sulphur, and carbonate of soda. It would therefore appear, from the preceding details, that ultramarine may be regarded as a compound of silicate of alumina, and silicate of soda, with sulphide of sodium, and that to the reaction of the last constituent upon the former its colour is due.

The constituents used in the different methods of making ultramarine vary in character and in quantity. It is said that a good mixture may consist of:—dried kaolin, 100; calcined Glauber salt, or sulphate of soda, 41; calcined soda, 41; pulverised charcoal or coal, 17; and sulphur, 13. When such a mixture is heated without access of air it yields a product from which a white substance may be obtained, known as *white ultramarine*. Calcined in crucibles at a high temperature, with a very limited supply of air, the mixture affords a semi-fused greenish mass termed *green ultramarine*. By carefully roasting this with sulphur at a low temperature, with free access of air, the ordinary *blue ultramarine* is obtained; and this when powdered, lixiviated, and dried, is ready for the market.

It appears that potash-salts cannot be substituted for soda-salts in the manufacture of ultramarine, but it is said that those of baryta may be so employed. In some cases, silica is added to the ultramarine mixture in the proportion of from 5 to 10 per cent.

Both native and artificial ultramarine have been examined very carefully by several eminent chemists. The following are a few specimens of these analyses:—

Analysis of Ultramarine, by Warrentrap.

	Lapis-lazuli.	Artificial from Meissen.	Blue.	Green.
Potash		1·75		
Soda	9·09	21·47	40·0	25·5
Alumina	31·07	23·30	29·5	30·0
Silica	42·50	45·00	40·0	39·9
Sulphur	0·95	1·68	4·0	4·6
Lime	3·52	0·02		
Iron	0·86	1·06	1·0	0·9
Chlorine	0·42			
Sulphuric acid	5·89	3·83	3·4	0·4
Water	0·12			

	Parisian artificial ultramarine, *by C. G. Gmelin.*
Soda and potash	12·863
Lime	1·546
Alumina	22·000
Silica	47·306
Sulphuric acid	4·679
Resin, sulphur, and loss	12·218

Notwithstanding the many investigations which have been made of ultramarine, its chemical composition is by no means thoroughly understood; and the German Association of Ultramarine Makers have recently (1874) offered a prize for the best essay on this subject, from which, it may be hoped, more light will be thrown upon the constitution of this compound.

ULVA. A seaweed used in the preparation of Green Laver. See ALGÆ.

UMBER. A mechanical mixture of limonite (brown hæmatite) and hydrated oxide of manganese and clay. It occurs in beds with brown jasper in the island of Cyprus. It is used by painters as a brown colour, raw or burnt.

UNGUENTS. The name given by engineers to the greases applied to the bearing parts of machinery. Unguents should be thick for heavy pressures, that they may resist being forced out; and thin for light pressures, that their viscidity may not add to the resistance to motion.—*Rankine.*

UNION GOODS. Cloths of a mixed character, as of flax and jute, or cotton and jute.

UPAS TREE. The *Antiaris toxicaria*, one of the order to which the bread-fruit tree belongs. Fabulous tales have been told of its poisonous nature; if wounded, a juice exudes which, when introduced into the human system, produces vomiting, purging, and finally death.

URANITE. Two varieties of this mineral are known: the one is *Copper-uranite*, or *Torbernite*, a phosphate of uranium and copper; and the other, *Lime-uranite*, or *Autunite*, a phosphate of uranium and lime.

URANIUM is one of the rare metals, and was first discovered by Klaproth in 1786 in the mineral called *pechblende*, which was, previously to this, mistaken for an ore of zinc. He called it Uranium after the planet discovered by Herschel about the same time. The ores of uranium are few; the principal being, *Pechblende* (*pitchblende*), a brownish or velvet-black mineral, which is essentially a proto-peroxide of uranium. It occurs in veins with ores of lead and silver in Saxony, and with tin in Cornwall. *Uranite*, a phosphate of copper and uranium, occurs in France; and is found of great beauty near Callington and near Redruth in Cornwall. *Samarskite* and *urano-tantalite* contain oxide of uranium with yttria and niobic acid. *Johannite*, uran-vitriol, or sulphate of uranium. *Zippeite*, sulphate of sesquioxide of uranium. *Uranochre*, an earthy yellow impure oxide of uranium.

The metal itself can only be obtained by the intervention of potassium or sodium, in the same manner as magnesium. It is a black coherent powder, or a white malleable metal, according to the state of aggregation. It is not oxidised by air or water, but very combustible when exposed to heat. It unites also with great violence with chlorine and with sulphur. M. Peligot admits three distinct oxides of uranium, and two other compounds of the metal and oxygen, which he designates as suboxides.

Protoxide, UO.—This is a brown powder, sometimes highly crystalline.

Proto-sesquioxide; black oxide; U^4O^5, or $2UO + U^2O^3$.—This oxide was formerly considered as the protoxide, and is produced whenever either of the other oxides are strongly heated in the air.

Sesquioxide, U^2O^3.—This is the best known and most important of the oxides. It forms a number of beautiful yellow salts; its colour, when prepared by heating the nitrate to 480° in an oil-bath till no more nitrous fumes are disengaged, is a chamois yellow. It may be obtained from *pitchblende*.

The only application of uranium is to enamel-painting and glass-staining; the protoxide giving a fine black colour, probably by absorbing oxygen and becoming black oxide, and the sesquioxide a delicate yellow.

Uranium has been found in a German blue pigment used by paper-hanging manufacturers: it contained both copper and uranium.

URANIUM YELLOW. Uranate of soda, used as a yellow colour for porcelain painting.

URAO. See NATRON.

UREA. This is one of the principal constituents of urine, being always present in it, but in variable quantities; the average quantity in healthy urine is about 14 or 15 parts in 1,000 of urine, but of course this varies from several circumstances, as in disease, drinking a large quantity of liquid, &c. The urine passed the first in the morning gives a fair estimate of the quantity of urea yielded by the urine of an individual. It seems to be the principal form in which the waste nitrogenous compounds of the body are eliminated from the system. As this animal product has no direct use in the arts, the reader may be referred to Watts's 'Dictionary of Chemistry,' or to any modern treatise on Animal Chemistry.

USQUEBAUGH (*Irish*). A name given to whisky occasionally, but usually applied to a liqueur prepared from whisky, or some other ardent corn-spirit. The following liqueurs, as being of a similar character, are named here. *Kirschwasser* is obtained in Switzerland and in some parts of France, from bruised black cherries fermented and distilled. *Maraschino* is a similar liqueur, prepared also from a peculiar kind of cherry growing in Dalmatia. *Noyau* and several analogous liqueurs are flavoured with an essential oil, containing more or less hydrocyanic acid and often with that derived from bitter almonds, the kernels of peaches, apricots, &c., or from the leaves of laurels. Some of these compounds come under the denomination of *tinctures*; such, for instance, as *Curaçoa*, which is prepared by digesting orange-berries (the immature fruit) and bitter orange-peal, with cloves and cinnamon, in brandy. When this tincture is distilled and afterwards sweetened, it constitutes *White Curaçoa.* The compounds are frequently called *Ratafias*: a term derived, like the word 'ratify,' from *ratum* and *fio*, 'to make firm,' 'or confirm.' By Ratafia, therefore, was originally meant a liquid drank at the *ratification* of an agreement.

V

VAALITE. A name recently given by Prof. Maskelyne to a variety of vermiculite, occurring in the diamond-bearing rocks of South Africa. It takes its name from the Vaal River.

VACUUM PAN. For a description of it, see SUGAR.

VALONIA is a kind of acorn, imported from the Levant and the Morea, for the use of tanners, as the husk or cup contains abundance of tannin. See LEATHER.

Valonia *Imported* in 1873:—

	Tons	Value
From Austrian Territories .	1,141	£20,793
„ Greece	3,598	58,699
„ Turkey	24,233	443,899
„ Other countries . .	5	99
Total	28,977	524,490

Valonia *Exported* in 1873:—

	Tons	Value
To Germany	196	£3,848
„ Belgium	202	3,927
„ Other countries . . .	208	4,034
Total	606	11,809

VALUE. Two methods have been adopted for ascertaining the value of our exports; one by means of the *official* value, the other according to the *declared* value. In Lowe's 'Present State of England' (1822), there is a very succinct and clear account of these methods, which is here extracted:—

'The *official* value of goods means a computation of value formed with reference, not to the prices of the current year, but to a standard, fixed so long ago as 1696, the time when the office of Inspector-General of the Imports and Exports was established, and a Custom-house ledger opened to record the weight, dimensions, and value of the merchandise that passed through the hands of the officers. One uniform rule is followed, year by year, in the valuation, some goods being estimated by weight, others by the dimensions, the whole without reference to the market price. This course has the advantage of exhibiting, with strict accuracy, every increase or decrease in the quantity of our exports.

Next as to the value of these exports in the market:—In 1798 there was imposed a duty of 2 per cent. on our exports, the value of which was taken, not by the official standard, but by the declaration of the exporting merchants. Such a declaration may be assumed as a representation of, or at least an approximation to, the market price of merchandise, there being on the one hand no reason to apprehend that merchants would pay a percentage on an amount beyond the market value, while on the other the liability to seizure afforded a security against under valuation.' See IMPORTS and EXPORTS.

VANADINITE. A vanadate of lead, with chloride of lead, occurring at Wanlock Head, in Dumfriesshire, and in Siberia and Mexico.

VANADIUM is a metal discovered by Sefström, in 1830, in a Swedish iron extracted from the iron ores of Taberg, not far from Jönköping. Its name is derived from Vanadis, a Scandinavian idol. This metal has been found as vanadate of lead, in the mineral *Vanadinite,* and it has been detected in the copper-bearing sandstone of Alderley Edge, in Cheshire. Vanadium is white, and when its surface is polished it resembles silver or molybdenum more than any other metal. It combines with oxygen to form four oxides. The compounds of vanadium have recently been studied by Prof. Roscoe.

The vanadate of ammonia, mixed with infusion of nutgalls, forms a black liquid, which is a very excellent writing-ink.

VANADIUM BRONZE. See BRONZE POWDERS.

VANILLA, or **VANILLE,** is the oblong narrow pod of various species of *Vanilla* (as *V. aromatica* and *V. planifolia*), of the natural family *Orchideæ*, which grows in Mexico, Columbia, Peru, and on the banks of the Oronoco.

The best comes from the forests round the village of Zentila, in the Intendancy of Oaxaca. The vanilla plant is cultivated in Brazil, in the West Indies, and some other tropical countries, but does not produce fruit of such a delicious aroma as in Mexico. It clings like a parasite to the trunks of old trees, and sucks the moisture which their bark derives from the lichens, and other cryptogams, but without drawing the nourishment from the tree itself. The fruit is subcylindric, about 8 inches long, one-celled, siliquose, and pulpy within. It should be gathered before it is fully ripe.

When about 12,000 of these pods are collected, they are strung like a garland by their lower end, as near as possible to the foot-stalk; the whole are plunged for an instant in boiling water to blanch them; they are then hung up in the open air, and exposed to the sun for a few hours. Next day they are lightly smeared with oil, by means of a feather, or the fingers; and are surrounded with oiled cotton, to prevent the valves from opening. As they become dry, on inverting their upper end they discharge a viscid liquid from it, and they are pressed at several times with oiled fingers, to promote its flow. The dried pods lose their appearance, grow brown, wrinkled, soft, and shrink into one-fourth of their original size. In this state they are touched a second time with oil, but very sparingly; because, with too much oil, they would lose much of their delicious perfume. They are then packed for the market, in small bundles of 50 to 100 in each, enclosed in lead-foil, or tight metallic cases. As it comes to us, vanilla is a capsular fruit, of the thickness of a swan's quill, strait, cylindrical, but somewhat flattened, truncated at the top, thinned off at the ends, glistening, wrinkled, furrowed lengthwise, flexible, from 5 to 10 inches long, and of a reddish-brown colour. It contains a pulpy parenchyma, soft, unctuous, very brown, in which are embedded black, brilliant, very small seeds. Its smells ambrosial and aromatic; its taste is hot, and rather sweetish. These properties seem to depend upon an essential oil, and also upon benzoic acid, which forms efflorescences upon the surface of the fruit. The pulpy part possesses alone the aromatic quality.

The kind most esteemed in France is called *leq* vanilla: it is about six inches long, from $\frac{1}{4}$ to $\frac{1}{3}$ of an inch broad, narrowed at the two ends, and curved at the base, somewhat soft and viscid, of a dark-reddish colour, and of a most delicious flavour, like that of balsam of Peru. It is called vanilla *givrées*, when it is covered with efflorescences of benzoic acid, after having been kept in a dry place, and in vessels not hermetically closed.

The second sort, called *vanilla simarona*, or bastard, is a little smaller than the preceding, of a less deep brown hue, drier, less aromatic, destitute of efflorescence. It is said to be the produce of the wild plant, and is brought from St. Domingo.

A third sort, which comes from Brazil, is the *vanillon*, or large vanilla of the French market; the *vanilla pamprona* or *bova* of the Spaniards. Its length is from 5 to 6 inches; its breadth from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch. It is brown, soft, viscid, almost always open, of a strong smell, but less agreeable than the *leq*. It is sometimes a little spoiled by an incipient fermentation. It is cured with sugar, and enclosed in tin-plate boxes, which contain from 20 to 60 pods.

Vanilla, as an aromatic, is much sought after by makers of chocolate, ices, and creams; by confectioners, perfumers, and liquorists, or distillers. It is difficultly reduced to fine particles; but it may be sufficiently attenuated by cutting it into small bits, and grinding these along with sugar. The odorous principle can, for some purposes, be extracted by alcohol.

Some researches recently conducted in Dr. Hofmann's laboratory at Berlin, by MM. Tiemann and Haarmann, have led to the successful preparation of a substance which appears to be identical in chemical and physical properties with *vanillin* or the aromatic principle of vanilla. The cambium of coniferous trees contains a crystallisable glucoside called *coniferin*; submitted to the action of ferments, coniferin is resolved into glucose and a crystalline product, which, under the influence of oxidising agents, such as a mixture of bichromate of potash and sulphuric acid, gives rise to the formation of *vanillin*, or the aromatic principle of vanilla. The manufacture of artificial vanillin on a commercial scale is about to be commenced (1874).

VAPOUR (*Vapeur*, Fr.; *Dampf*, Ger.) is the state of elastic or aëriform fluidity into which any substance, naturally solid or liquid at ordinary temperatures, may be converted by the agency of heat. A *visible* fluid floating in the atmosphere, as distinguished from a gas which is ordinarily, unless it be coloured as chlorine gas, invisible. The vapour of water is STEAM.

VAREC. The name of kelp made on the coast of Normandy. See KELP and VRAC.

VARNISH (*Vernis*, Fr.; *Firniss*, Ger.) is a solution of resinous matter, which is spread over the surface of any body, in order to give it a shining, transparent, and hard coat, capable of resisting, in a greater or less degree, the influences of air and moisture. Such a coat consists of the resinous parts of the solution, which remain in a thin layer upon the surface after the liquid solvent has either evaporated away, or has dried up. When large quantities of spirit-varnish are to be made, a common still, mounted with its capital and worm, is the vessel employed for containing the materials, and it is placed in a steam- or water-bath. The capital should be provided with a stuffing-box, through which a stirring-rod may pass down to the bottom of the still, with a cross-piece to its lower end, and a handle or winch at its top. After heating the bath till the alcohol boils and begins to distil, the heat ought to be lowered, that the solution may continue to proceed in an equable manner, with as little evaporation of spirit as possible. The operation may be supposed to be complete when the rod can be easily turned round. The varnish must be passed through a silk sieve of proper fineness; then filtered through porous paper, or allowed to clear leisurely in stone jars. The alcohol which has come over should be added to the varnish, if the just proportions of the resins have been introduced at first.

The building or shed wherein varnish is made, ought to be quite detached from any buildings whatever, to avoid accidents by fire. For general purposes, a building about 18 feet by 16 is sufficiently large for manufacturing 4,000 gallons and upwards annually, provided there are other convenient buildings for the purpose of holding the utensils, and warehousing the necessary stock.

Procure a copper pan made like a common washing-copper, which will contain from 50 to 80 gallons, as occasion may require; when wanted, set it upon the boiling furnace, and fill it up with linseed oil within 5 inches of the brim. Kindle a fire in the furnace underneath, and manage the fire so that the oil shall gradually, but slowly, increase in heat for the first two hours; then increase the heat to a gentle simmer; and if there is any scum on the surface, skim it off with a copper ladle, and put the skimming away. Let the oil boil gently for three hours longer; then introduce, by a little at a time, one quarter of an ounce of the best calcined magnesia for every gallon of oil, occasionally stirring the oil from the bottom. When the magnesia is all in, let the oil boil rather smartly for one hour; it will then be sufficient. Lay a cover over the oil, to keep out the dust while the fire is withdrawn and extinguished by water; next uncover the oil, and leave it till next morning; and then while it is yet hot, ladle it into the carrying-jack, or let it out through the pipe and cock; carry it away, and deposit it in either a tin or leaden cistern, for wooden vessels will not hold it; let it remain to settle for at least three months. The magnesia will absorb all the acid and mucilage from the oil, and fall to the bottom of the cistern, leaving the oil clear and transparent, and fit for use. Recollect when the oil is taken out not to disturb the bottoms, which are only fit for black paint.

General Observations and Precautions to be observed in making Varnishes.—Set on the boiling-pot with 8 gallons of oil; kindle the fire; then lay the fire in the gum-furnace; have as many 8lb.-bags of gum copal all ready weighed up as will be wanted; put one 8lb. into the pot, put fire to the furnace, set on the gum-pot: in three minutes (if the fire is brisk) the gum will begin to fuse and give out its gas, steam, and acid; stir and divide the gum, and attend to the rising of it, as before directed. 8 lbs. of copal take in general from sixteen to twenty minutes in fusing, from the beginning till it gets clear like oil, but the time depends very much on the heat of the fire and the attention of the operator. During the first twelve minutes while the gum is fusing, the assistant must look to the oil, and bring it to a smart simmer; for it ought to be neither too hot nor too cold, but in appearance beginning to boil, which he is strictly to observe, and when ready to call out, 'Bear a hand!' Then immediately both lay hold of a handle of the boiling-pot, lift it right up so as to clear the plate, carry it out and place it on the ash-bed, the maker instantly returning to the gum-pot, while the assistant puts three copper ladlefuls of oil into the copper pouring-jack, bringing it in, and placing it on the iron plate at the back of the gum-pot to keep hot until wanted. When the maker finds the gum is nearly all completely fused, and that it will in a few minutes be ready for the oil, let him call out, 'Ready oil!' The assistant is then to lift up the oil-jack with both hands, one under the bottom and the other on the handle, laying the spout over the edge of the pot, and wait until the maker calls out 'Oil!' The assistant is then to pour in the oil as before directed, and the boiling to be continued until the oil and gum become concentrated, and the mixture looks clear on the glass; the gum-pot is now to be set upon the brick-stand until the assistant puts three more ladlefuls of hot oil into the pouring-jack, and three more into a spare tin for the third run of gum. There will remain in the boiling-pot still 3½ gallons of oil. Let the maker put his right hand down the handle of the gum-pot near to the side, with his left hand near the end of the handle, and with a firm grip lift the gum-pot, and deliberately lay the edge of the gum-pot over the edge of the boiling-pot, until all its contents run into the boiling-pot. Let the gum-pot be held, with its bottom turned upwards for a minute, right over the boiling-pot. Observe, that whenever the maker is beginning to pour, the assistant stands ready with a thick piece of old carpet without holes, and sufficiently large to cover the mouth of the boiling-pot should it catch fire during the pouring, which will sometimes happen if the gum-pot is very hot; should the gum-pot fire, it has only to be kept bottom upwards, and it will go out of itself; but if the boiling-pot should catch fire during the pouring, let the assistant throw the piece of carpet quickly over the blazing pot, holding it down all round the edges; in a few minutes it will be smothered. The moment the maker has emptied the gum-pot, he throws into it half-a-gallon of turpentine, and with the *swish* immediately washes it from top to bottom, and instantly empties it into the flat tin jack: he wipes the pot dry, and puts in 8 lbs. more gum, and sets it upon the turnace; proceeding with this run exactly as with the last, and afterwards with the third run. There will then be 8 gallons of oil, and 24 lbs. of gum in the boiling-pot, under which keep up a brisk strong fire until a scum or froth rises and covers all the surface of the contents, when it will begin to rise rapidly. Observe, when it rises near the rivets of the handles, carry it from the fire and set it on the ash-bed, stir it down again, and scatter in the driers by a little at a time; keep stirring, and if the frothy head goes down put it upon the furnace, and introduce *gradually* the remainder of the driers, always carrying out the pot when the froth rises near the rivets. In general, if the fire be good, all the time a pot requires to boil from the time of the last gum being poured in, is about three and a half or four hours: but *time* is no criterion for a beginner to judge by, as it may vary according to the weather, the quality of the oil, the quality of the gum, the driers, or the heat of the fire, &c.; therefore, about the third hour of boiling, try it on a bit of glass, and keep it boiling, until it feels strong and stringy between the fingers; it is then boiled sufficiently to carry it on the ash-bed, and to be stirred down until it is cold enough to mix, which will depend much on the weather, varying from half an hour in dry frosty weather to one hour in warm summer weather. Previous to beginning to mix, have a sufficient quantity of turpentine ready, fill the pot, and pour in, stirring all the time at the top or surface, as before directed, until there are 15 gallons, or five tins of oil of turpentine introduced, which will leave it quite thick enough if the gum is good, and has been well run; but if the gum was of a weak quality, and has not been well fused, there ought to be no more than 12 gallons of turpentine mixed, and even that may be too much. Therefore, when 12 gallons of turpentine have been introduced, have a flat saucer at hand, and pour into it a portion of the varnish, and in two or three minutes it will show whether it is too thick; if not sufficiently thin, add a little more turpentine, and strain it off quickly. As soon as the whole is stored away, pour in the turpentine washings with which the gum-pots have been washed, into the boiling-pot, and with the swish quickly wash down all the varnish from the pot sides; afterwards, with a large piece of woollen rag dipped in pumice-powder, wash and polish every part of the inside of the boiling-pot, performing the same operation on the ladle and stirrers; rinse them with the turpentine washings, and at last rinse them altogether in clean turpentine, which also put to the washings; wipe dry with a clean soft rag the pot, ladle, stirrer, and funnels, and lay the sieve so as to be completely covered with turpentine, which will always keep it from gumming up. The foregoing directions concerning running the gum and pouring in the oil, and also boiling off and mixing, are, with very little difference, to be observed in the making of all sorts of copal varnishes, except the differences of the quantities of oil, gum, &c., which will be found under the various descriptions by name, which will be hereafter described.

The choice of linseed oil is of peculiar consequence to the varnish-maker. Oil from fine full-grown ripe seed, when viewed in a phial, will appear limpid, pale, and brilliant; it is mellow and sweet to the taste, has very little smell, is specifically lighter than impure oil, and, when clarified, dries quickly and firmly, and does not materially change the colour of the varnish when made, but appears limpid and brilliant.

Copal Varnishes for fine paintings, &c.—Fuse 8 lbs. of the very cleanest pale African gum copal, and, when completely run fluid, pour in two gallons of hot oil, old measure; let it boil until it will string very strong; and in about fifteen minutes, or while it is yet very hot, pour in three gallons of turpentine, old measure, and got from the top of a cistern. Perhaps during the mixing a considerable quantity of the turpentine will escape; but the varnish will be so much the brighter, transparent, and fluid; and will work freer, dry more quickly, and be very solid and durable when dry. After the varnish has been strained, if it is found too thick, before it is quite cold, heat as much turpentine, and mix with it, as will bring it to a proper consistency.

Cabinet Varnish.—Fuse 7 lbs. of very fine African gum copal, and pour in half a gallon of pale clarified oil; in three or four minutes after, if it feel stringy, take it out of doors, or into another building where there is no fire, and mix with it three gallons of turpentine; afterwards strain it, and put it aside for use. This, if properly boiled, will dry in ten minutes; but if too strongly boiled, will not mix at all with the turpentine; and *sometimes*, when boiled with the turpentine, will mix, and yet refuse to incorporate with any other varnish less boiled than itself: therefore it requires a nicety which is only to be learned from practice. This varnish is chiefly intended for the use of japanners, cabinet-painters, coach-painters, &c.

Best-body Copal Varnish, for coach-makers, &c.—This is intended for the body parts of coaches and other similar vehicles, intended for polishing.

Fuse 8 lbs. of fine African gum copal; add two gallons of clarified oil (old measure); boil it very slowly for four or five hours, until quite stringy; mix with three gallons and a half of turpentine; strain off, and pour it into a cistern. As they are too slow in drying, coach-makers, painters, and varnish-makers have introduced to two pots of the preceding varnish one made as follows:—

8 lbs. of fine pale gum animé;
2 gallons of clarified oil;
3½ gallons of turpentine.
To be boiled four hours.

The more minutely the gum copal is run, or fused, the greater the quantity, and the stronger the produce. The more regular and longer the boiling of the oil and gum together is continued, the more fluid or free the varnish will extend on whatever it is applied to. When the mixture of oil and gum is too suddenly brought to string by too strong a heat, the varnish requires more than its just proportion of turpentine to thin it, whereby its oily and gummy quality is reduced, which renders it less durable; neither will it flow so well in laying on. The greater proportion of oil there is used in varnishes, the less they are liable to crack, because the tougher and softer they are. By increasing the proportion of gum in varnishes, the thicker will be the stratum, the firmer they will set solid, and the quicker they will dry. When varnishes are quite new made, and must be sent out for use before they are of sufficient age, they must always be left thicker than if they were to be kept the proper time. Varnish made from African copal alone possesses the most elasticity and transparency. Too much drier in varnish renders it opaque and unfit for delicate colours. Copperas does not combine with varnish, but only hardens it. Sugar of lead does combine with varnish. Turpentine improves by age; and varnish by being kept in a warm place. All copal- or oil-varnishes require age before they are used.

All body-varnishes are intended and ought to have 1½ lb. of gum to each gallon of varnish, when the varnish is strained off and cold; but as the *thinning up*, or quantity of turpentine required to bring it to its proper consistency, depends very much upon the degree of boiling the varnish has undergone, therefore, when the gum and oil have not been strongly boiled, it requires less turpentine for that purpose; whereas, when the gum and oil are very strongly boiled together, a pot of 20 gallons will require perhaps 3 gallons above the regular proportionate quantity; and if mixing the turpentine be commenced too soon, and the pot be not sufficiently cool, there will be frequently above a gallon and a half of turpentine lost by evaporation.

Pale Amber Varnish.—Fuse 6 lbs. of fine picked very pale transparent amber in the gum-pot, and pour in 2 gallons of hot clarified oil. Boil it until it strings very strong. Mix with 4 gallons of turpentine. This will be as fine as body-copal, will work very free, and flow well upon any work it is applied to: it becomes very hard, and is the most durable of all varnishes.

Fine Mastic, or Picture Varnish.—Put 5 lbs. of fine picked gum mastic into a new 4-gallon tin bottle; get ready 2 lbs. of glass, bruised as small as barley; and put it into the bottle with 2 gallons of turpentine that has settled some time; put a piece of soft leather under the bung; lay the tin on a sack upon the counter, table, or anything that stands solid; begin to agitate the tin, smartly rolling it backward and forward, causing the gum, glass, and turpentine, to work as if in a barrel-churn for at least 4 hours, when the varnish may be emptied out. If the gum is not all dissolved, return the whole into the bottle, and agitate as before, until all the gum is dissolved; then strain it through fine thin muslin into a clean tin bottle: leave it uncorked, so that the air can get in, but no dust; let it stand for nine months at least before it is used, for the longer it is kept the tougher it will be, and less liable to chill or bloom.

Common Mastic Varnish.—Put as much gum mastic, unpicked, into the gum-pot as may be required, and to every 2¾ lbs. of gum pour in 1 gallon of cold turpentine; set the pot over a very moderate fire, and stir it with the stirrer; be careful, when the steam of the turpentine rises near the mouth of the pot, to cover it with the carpet, and carry it out of doors, as the vapour is very apt to catch fire. A few minutes' low heat will perfectly dissolve 8 lbs. of gum, which will, with 4 gallons of turpentine, produce, when strained, 4½ gallons of varnish; to which add, while yet hot, 5 pints of pale turpentine varnish, which improves the body and hardness of the mastic varnish.

Crystal Varnish.—Procure a bottle of Canada balsam, and set the bottle of balsam at a little distance from the fire, turning it round several times, until the heat has thinned it; then have something that will hold as much as double the quantity of balsam; carry the balsam from the fire, and, while fluid, mix it with the same quantity of good turpentine, and shake them together until they are well incorporated: in a few days the varnish is fit for use. This varnish is used for maps, prints, charts, drawings, paper-ornaments, &c.; and when made upon a larger scale, requires only warming the balsam to mix with the turpentine.

White Hard Spirit of Wine Varnish.—Put 5 lbs. of gum sandarac into a 4-gallon tin bottle, with 2 gallons of spirits of wine, 60 over proof, and agitate it until dissolved, exactly as directed for the best mastic varnish, recollecting if glass is used that it is convenient to dip the bottle containing the gum and spirits into a copperful of hot water every 10 minutes—the bottle to be immersed only 2 minutes at a time—which will greatly assist the dissolving of the gum; but, above all, be careful to keep a firm hold over the cork of the bottle, otherwise the vapour will drive it out. The bottle, every time it is heated, ought to be carried away from the fire; the cork should be eased a little, to allow the rarefied air to escape; then driven tight, and the agitation continued in this manner until all the gum is properly dissolved. After it is strained off, put into the varnish 1 quart of very pale turpentine varnish, and shake and mix the two well together. Spirit varnishes should be kept well corked: they are fit to use the day after being made.

Brown Hard Spirit Varnish is made by putting into a bottle 3 lbs. of gum sandarac, with 2 lbs. of shellac, add 2 gallons of spirits of wine, 60 over proof; proceeding exactly as before directed for the white hard varnish, and agitating it when cold, which requires about four hours' time, without any danger of fire; whereas, making any spirit varnish by heat is always attended with danger. No spirit varnish ought to be made either near a fire or by candle-light. When this brown hard is strained, add 1 quart of turpentine varnish, and shake and mix it well: next day it is fit for use.

The *Chinese Varnish* comes from a tree which grows in Cochin-China, China, and Siam. It forms the best of all varnishes.

Gold Lacker.—Put into a clean 4-gallon tin, 1 lb. of ground turmeric, 1½ ounce of powdered gamboge, 3½ lbs. of powdered gum sandarac, ¾ of a pound of shellac, and 2 gallons of spirits of wine. After being agitated, dissolved. and strained, add 1 pint of turpentine varnish, well mixed.

Red Spirit Lacker.

2 gallons of spirits of wine;
1 lb. of dragon's blood;
3 lbs. of Spanish annotto;
3¼ lbs. of gum sandarac;
2 pints of turpentine.
Made exactly as the yellow gold lacker.

Pale Brass Lacker.

2 gallons of spirits of wine;
3 ounces of Cape aloes, cut small;
1 lb. of fine pale shellac;
1 ounce gamboge, cut small.
No turpentine varnish. Made exactly as before.

White Spirit Varnish.—Sandarac, 250 parts; mastic in tears, 64; elemi resin, 32; turpentine (Venice), 64; alcohol, of 85 per cent., 1,000 parts by measure.

The turpentine is to be added after the resins are dissolved. This is a brilliant varnish, but not so hard as to bear polishing.

Varnish for the Wood Toys of Spa.—Tender copal, 75 parts; mastic, 12·5; Venice turpentine, 6·5; alcohol, of 95 per cent., 100 parts by measure; water ounces, for example, if the other parts be taken in ounces.

The alcohol must be first made to act upon the copal, with the aid of a little oil of lavender or camphor, and the solution being passed through a linen cloth, the mastic must be introduced. After it is dissolved, the Venice turpentine, previously melted in a water-bath, should be added; the lower the temperature at which these operations are carried on, the more beautiful will the varnish be. This varnish ought to be very white, very drying, and capable of being smoothed with pumice-stone and polished.

The Varnish of Watin, for Gilded Articles.—Gum lac, in grain, 125 parts; gamboge, 125; dragon's blood, 125; annotto, 125; saffron, 32. Each resin must be dissolved in 1,060 parts by measure of alcohol of 90 per cent.; two separate tinctures must be made with the dragon's blood and annotto, in 1,000 parts of such alcohol; and a proper proportion of each should be added to the varnish, according to the shade of golden colour wanted.

For fixing engravings or lithographs upon wood, a varnish called *mordant* is used in France, which differs from others chiefly in containing more Venice turpentine, to make it sticky; it consists of—sandarac, 250 parts; mastic, in tears, 64; resin, 125; Venice turpentine, 250; alcohol, 1,000 parts by measure.

Milk of Wax is a valuable varnish, which may be prepared as follows:—Melt in a porcelain capsule a certain quantity of white wax, and add to it, while in fusion, an equal quantity of spirit of wine, of sp. gr. 0·830; stir the mixture, and pour it upon a large porphyry slab. The granular mass is to be converted into a paste by the muller, with the addition, from time to time, of a little alcohol; and as soon as it appears to be smooth and homogeneous, water is to be introduced in small quantities successively, to the amount of four times the weight of the wax. This emulsion is to be then passed through canvas, in order to separate such particles as may be imperfectly incorporated. The *milk of wax*, thus prepared, may be spread with a smooth brush upon the surface of a painting, allowed to dry, and then fused by passing a hot iron (salamander) over its surface. When cold, it is to be rubbed with a linen cloth to bring out the lustre.

Black Japan is made by putting into the set-pot 48 lbs. of Naples or any other of the foreign asphaltums (except the Egyptian). As soon as it is melted, pour in 10 gallons of raw linseed oil; keep a moderate fire, and fuse 8 lbs. of dark gum animé in the gum-pot; mix it with 2 gallons of hot oil, and pour it into the set-pot. Afterwards fuse 10 lbs. of dark or sea amber in the 10-gallon iron-pot; keep stirring it while fusing; and whenever it appears to be overheated, and rising too high in the pot, lift it from the fire for a few minutes. When it appears completely fused, mix in 2 gallons of hot oil, and pour the mixture into the set-pot; continue the boiling for 3 hours longer, and during that time introduce the same quantity of driers as before directed: draw out the fire, and let it remain until morning; then boil it until it rolls hard, as before directed: leave it to cool, and afterwards mix with turpentine.

Best Brunswick Black.—In an iron pot, over a slow fire, boil 45 lbs. of foreign asphaltum for at least 6 hours; and during the same time boil in another iron pot 6 gallons of oil which has been previously boiled. During the boiling of the 6 gallons introduce 6 lbs. of litharge gradually, and boil until it feels stringy between the fingers; then ladle or pour it into the pot containing the boiling asphaltum. Let the mixture boil until, upon trial, it will roll into hard pills; then let it cool, and mix it with 25 gallons of turpentine, or until it is of a proper consistency.

Iron-work Black.—Put 48 lbs. of foreign asphaltum into an iron pot, and boil for 4 hours. During the first 2 hours introduce 7 lbs. of red lead, 7 lbs. of litharge, 3 lbs. of dried copperas, and 10 gallons of boiled oil; add 1 eight-pound run of dark gum, with 2 gallons of hot oil. After pouring the oil and gum, continue the boiling 2 hours, or until it will roll into hard pills like japan. When cool, thin it off with 30 gallons of turpentine, or until it is of a proper consistency. This varnish is intended for blacking the iron-work of coaches and other carriages, &c.

A cheap Brunswick Black.—Put 28 lbs. of common black pitch, and 28 lbs. of common asphaltum made from gas-tar, into an iron pot; boil both for 8 or 10 hours, which will evaporate the gas and moisture; let it stand all night, and early next morning, as soon as it boils, put in 8 gallons of boiled oil; then introduce, gradually, 10 lbs. of red lead and 10 lbs. of litharge, and boil for 3 hours, or until it will roll very hard. When ready for mixing, introduce 20 gallons of turpentine, or more, until of a proper consistency. This is intended for engineers, founders, ironmongers, &c. It will dry in half an hour, or less, if properly boiled.

VEGETABLE BUTTER. A fatty substance expressed from the seeds of an Indian tree, the *Bassia butyracea*, Roxb. It is said to make good soap.

VEGETABLE ETHIOPS. A charcoal prepared by the incineration in a covered crucible of the *Fucus vesiculosus*, or common sea-wrack.

VEGETABLE FIBRE. Most of the useful vegetable fibres are described under their proper heads, as FLAX, HEMP, &c. See also FIBRES, and FIBRE, VEGETABLE.

VEGETABLE IVORY. See COROSA NUTS, and IVORY, VEGETABLE.

VEGETABLE PARCHMENT. See PARCHMENT, VEGETABLE.

VEINS (*Filons*, Fr.; *Gänge*, Ger.) are the fissures or rents in rocks, which are filled with peculiar mineral substances, most commonly metallic ores. See MINES, MINING, &c.

VEIN-STONES are the mineral substances which accompany, and frequently enclose, the metallic ores. See MINES, MINING, &c.

VELLUM is a fine sort of parchment. See PARCHMENT.

VELVET (*Vélours*, Fr.; *Sammet*, Ger.). A peculiar stuff, the nature of which is explained under FUSTIAN and TEXTILE FABRICS.

VENETIAN CHALK is STEATITE.

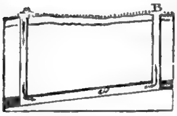
VENETIAN WHITE. A carefully-prepared carbonate of lead. See White Lead.

VENICE TURPENTINE. A turpentine obtained from the larch (*Larix Europæa*).

VENTILATION OF MINES. In our subterranean operations, especially where quantities of carbonic acid are constantly being produced by respiration and combustion, and where, as especially in our coal-mines, the workmen are constantly exposed to the efflux of a gas—light carburetted hydrogen, which, when mixed with air, becomes explosive, it is necessary to adopt the means of removing, as rapidly as possible, the atmosphere by which the miner is surrounded.

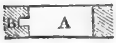
The production of noxious gases renders ventilation a primary object in the system of mining. If an air-pipe has been carried down the engine pit for the purpose of ventilation in the sinking, other pipes are connected with it, and laid along the pavement, or are attached to an angle of the mine next the roof. These pipes are prolonged with the galleries, by which means the air at the forehead is drawn up the pipes and replaced by atmospheric air, which descends by the shaft in an equable current, regulated by the draught of the furnace at the pit-mouth. This circulation is continued till the miners cut through upon the second shaft, when the air-pipes become superfluous; for it is well known that the instant such communication is made, as is represented in *fig.* 2068 *a*, the air spontaneously descends in the engine-pit A, and passing along the gallery *a*, ascends in a steady current in the second pit B. The air, in sinking through A, has at first the atmospheric temperature, which in winter may be at or under the freezing-point of water; but its temperature increases in passing down through the relatively warmer earth, and ascends in the shaft B, warmer than the atmosphere. When shafts are of unequal depths, as represented in the figure, the current of air flows pretty uniformly in one direction. If the second shaft has the same depth with the first, and the bottom and mouth of both be in the same horizontal plane, the air would sometimes remain at rest, as water would do in an inverted syphon, and at other times would circulate down one pit and up another, not always in the same direction, but sometimes up the one and sometimes up the other, according to the variations of temperature at the surface, and the barometrical pressures, as modified by winds. There is in mines a proper heat, proportional to their depth, increasing about one degree of Fahrenheit's scale for every 50 feet of descent.

2068 *a*



There is a simple mode of conducting air from the pit-bottom to the forehead of the mine, by cutting a *ragglin*, or *trumpeting*, as it is termed, in the side of the gallery, as represented in *fig.* 2069, where A exhibits the gallery in the coal, and B the ragglin, which is from 15 to 18 inches square. The coal itself forms three sides of the air-pipe, and the fourth is composed of thin deals applied air-tight, and nailed to small props of wood fixed between the top and bottom of the lips of the ragglin. This mode is very generally adopted in running galleries of communication, and dip-head level galleries, where carbonic acid abounds, or when from the stagnation of the air the miners' lights burn dimly.

2069

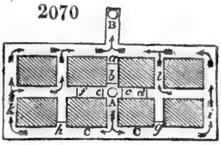


When the ragglin or air-pipes are not made spontaneously active, the air is sometimes impelled through them by means of ventilating-fanners, having their tube placed at the pit-bottom, while the vanes are driven with great velocity by a wheel and pinion worked with the hand. In other cases, large bellows like those of the blacksmith, furnished with a wide nozzle, are made to act in a similar way with the fanners. But these are merely temporary expedients for small mines.

Ventilation of mines and collieries has been likewise effected on a small scale, by attaching a horizontal funnel to the top of air-pipes elevated a considerable height above the pit-mouth. The funnel revolves on a pivot, and by its tail-piece places its mouth so as to receive the wind. At other times, a circulation of air is produced by placing coal-fires in iron grates, either at the bottom of an upcast pit, or suspended by a chain a few fathoms down.

In all great coal-mines the aërial circulation is regulated and directed by double doors, called main or bearing doors. These are true air-valves, which prevent the current of air moving in one direction from mixing with another moving in a different direction. Such valves are placed on the main roads and passages. Their functions are represented in the annexed *fig.* 2070: where A shows the downcast shaft, in which the aërial current is made to descend; B is the upcast shaft, sunk towards the rise of the coal; and C the dip-head level. Were the mine here figured to be worked without any attention to the circulation, the air would flow down the pit A, and proceed in a direct line up the rise mine to the shaft B, in which it would ascend. The consequence would therefore be, that all the galleries and boards to the dip of the pit A, and those lying on each side of the pits, would have no circulation of air; or, in the language of the collier, would be laid dead. To obviate this result, double doors are placed in three of the galleries adjoining the pit; viz. at *a* and *b*, *c* and *d*, *e* and *f*; all of which open inwards to the shaft A. By this plan, as the air is not suffered to pass directly from the shaft A to the shaft B, through the doors *a* and *b*, it would have taken the next shortest direction by *c d* and *e f*; but the doors in these galleries prevent this course, and compel it to proceed downwards to the dip-head level C, where it will spread or divide, one portion pursuing a route to the right, another to the left. On arriving at the boards *g* and *h*, it would have naturally ascended by them; but this it cannot do by reason of the building or stopping placed at *g* and *h*. By means of such stoppings placed in the boards next the dip-head level, the air can be transported to the right hand or to the left for many miles, if necessary, provided there be a train or circle of aërial communication from the pit A to the pit B. If the boards *i* and *k* are open, the air will ascend in them, as traced out by the arrows; and after being diffused through the workings, will again meet in a body at *a*, and mount the gallery to the pit B, sweeping away with it the deleterious air which it meets in its path. Without double doors on each main passage, the regular circulation of the air would be constantly liable to interruptions and derangements; thus, suppose the door *c* to be removed, and only *d* to remain in the left-hand gallery, all the other doors being as represented, it is obvious, that whenever the door *d* is opened, the air, finding a more direct passage in that direction, would mount by the nearest channel *l*, to the shaft B, and lay dead all the other parts of the work, stopping all circulation. As the passages on which the doors are placed constitute the main roads by which the miners go to and from their work, and as the corves are also constantly wheeling along, were a single door, such as *d*, so often opened, the ventilation would be rendered precarious or languid. But the double doors obviate this inconvenience; for both men and horses, with the corves, in going to or from the pit-bottom A, no sooner enter the door *d*, than it shuts behind them, and encloses them in the still air contained between the doors *d* and *c*; *c* having prevented the air from changing its proper course while *d* was open. When *d* is again shut, the door *c* may be opened without inconvenience, to allow the men and horses to pass on to the pit-bottom at A: the door *d* preventing any change in the aërial circulation while the door *c* is open. In returning from the pit, the same rule is observed of shutting one of the double doors before the other is opened.

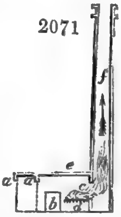
2070



When carbonic acid gas abounds, or when the fire-damp is in very small quantity, the air may be conducted from the shaft to the dip-head level, and by placing stoppings of each room next the level, it may be carried to any distance along the dip-head levels; and the farthest room on each side being left open, the air is suffered to diffuse itself through the wastes, along the wall faces, and mount in the upcast pit. But should the air become stagnant along the wall faces, stoppings are set up throughout the galleries, in such a way as to direct the main body of fresh air along the wall faces for the workmen, while a partial stream of air is allowed to pass through the stoppings, to prevent any accumulation of foul air in the wastes.

In very deep and extensive collieries more elaborate arrangements for ventilation are introduced. The circulation is made active by rarefying the air at the upcast shaft, by means of a large furnace placed either at the bottom or top of the shaft. The former position is generally preferred. *Fig.* 2071 exhibits a furnace placed at the top of the pit. A little way below the scaffold, a passage is previously cut, either in a sloping direction, to connect the current of air with the furnace, or it is laid horizontally, and then communicates with the furnace by a vertical opening. If any obstacle prevent the scaffold from being erected within the pit, this can be made air-tight at top, and a brick flue carried thence along the surface to the furnace.

2071

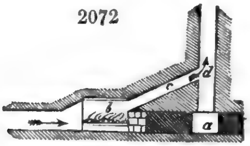


The furnace has a size proportional to the magnitude of the ventilation, and the chimneys are either round or square, being from 50 to 100 feet high, with an inside diameter of from 5 to 9 feet at bottom, tapering upwards to a diameter of from 2½ feet to 5 feet. Such stalks are made 9 inches thick in the body of the building, and a little thicker at bottom, where they are lined with fire-bricks.

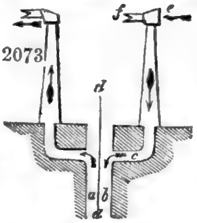
The plan of placing the furnace at the bottom of the pit is, however, more advantageous, because the shaft through which the air ascends to the furnace at the pit-mouth, is always at the ordinary temperature; whereas, when the furnace is situated at the bottom of the shaft, its sides get heated, like those of a chimney, through its total length, so that, though the heat of the furnace be accidentally allowed to decline or become extinct for a little, the circulation will still go on, the air of the upcast pit being rarefied by the heat remaining in the sides of the shaft.

To prevent the annoyance to the onsetters at the bottom from the hot smoke, the plan has been adopted, as shown in the wood-cut, *fig.* 2072, where *a* represents the lower part of the upcast shaft; *b*, the furnace, built of brick, arched at top, with its sides insulated from the solid mass of coal which surrounds it. Between the furnace wall and the coal-beds a current of air constantly passes towards the shaft, in order to prevent the coal catching fire. From the end of the furnace a gallery is cut in a rising direction at *c*, which communicates with the shaft at *d*, about 7 or 8 fathoms from the bottom of the pit. Thus the furnace and the furnace-keeper are completely disjoined from the shaft; and the pit-bottom is not only free from all incumbrances, but remains comfortably cool. To obviate the inconveniences from the smoke to the banksmen in landing the coals at the pit-mouth, the following plan has been contrived for the Newcastle collieries. *Fig.* 2073 represents the mouth of the pit: *a* is the upcast shaft, provided with a furnace at bottom; *b*, the downcast shaft, by which the supply of atmospheric air descends; and *d*, the brattice carried above the pit-mouth. A little way below the settle-boards, a gallery, *c*, is pushed, in communication with the surface from the downcast shaft, over which a brick tube or chimney is built from 60 to 80 feet high, 7 or 8 feet diameter at bottom, and 4 or 5 feet diameter at top. On the top of this chimney a deal funnel is suspended horizontally on a pivot, like a turn-cap. The vane *f*, made also of deal, keeps the mouth of the funnel always in the same direction with the wind. The same mechanism is mounted at the upcast shaft *a*, only here the funnel is made to present its mouth in the wind's eye. It is obvious from the figure, that a high wind will rather aid than check the ventilation by this plan.

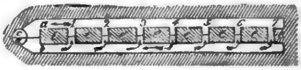
2072



2073



2074

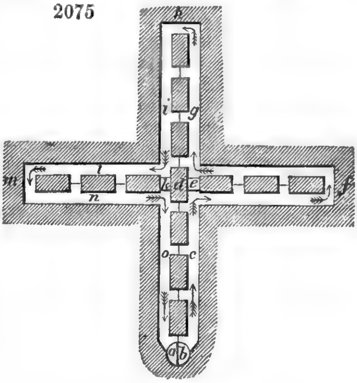


The principle of ventilation being established, the next object in opening up a colliery, and in driving galleries, is the *double mine* or double *headways course*; on the simple but ingenious distribution of which, the circulation of air depends at the commencement of the excavations.

The double headways course is represented in *fig.* 2074, where *a* is the one heading or gallery, and *b* the other; the former being immediately connected with the upcast side of the pit *c*, and the latter with the downcast side of the pit *d*. The pit itself is made completely air-tight by its division of deals from top to bottom, called 'the brattice wall'; so that no air can pass through the brattice from *d* to *c*, and the intercourse betwixt the two currents of air is completely intercepted by a stopping betwixt the pit-bottom and the end of the first pillar of coal; the pillars or walls of coal, marked *e*, are called 'stenting walls;' and the openings betwixt them, 'walls' or 'thirlings.' The arrows show the direction of the air. The headings *a* and *b* are generally made about 9 feet wide, the stenting-walls 6 or 8 yards thick, and are holed or thirled at such a distance as may be most suitable for the state of the air. The thirlings are 5 feet wide.

When the headings are set off from the pit-bottom, an aperture is left in the brattice at the end of the pillar next the pit, through which the circulation betwixt the upcast and downcast pits is carried on; but whenever the workmen cut through the first thirling No. 1, the aperture in the brattice at the pit-bottom is shut; in consequence of which the air is immediately drawn by the power of the upcast shaft through that thirling as represented by the dotted arrow. Thus a direct stream of fresh air is obviously brought close to the forehead where the mines are at work. The two headings *a* and *b* are then advanced, and as soon as the thirling No. 2 is cut through, a wall of brick and mortar, 4½ inches thick, is built across the thirling No. 1. This wall is termed 'a stopping;' and being air-tight, it forces the whole circulation through the thirling No. 2. In this manner the air is always led forward, and caused to circulate always by the last-made thirling next the forehead; care being had, that whenever a new thirling is made, the last thirling through which the air was circulated be secured with an air-tight stopping. In the woodcut, the stoppings are placed in the thirlings numbered 1, 2, 3, 4, 5, 6, and of consequence the whole circulation passes through the thirling No. 7, which lies nearest the foreheads of the headings, *a, b.* By inspecting the figure, we observe that on this very simple plan a stream of air may be circulated to any required distance, and in any direction, however tortuous. Thus, for example, if while the double headways course *a, b*, is pushed forward, other double headways courses are required to be carried on at the same time on both sides of the first headway, the same general principles have only to be attended to as shown in *fig.* 2075, where *a* is the upcast and *b* the downcast shaft. The air advances along the heading *c*, but cannot proceed farther in that direction than the pillar *d*, being obstructed by the double doors at *e*. It therefore advances in the direction of the arrows to the foreheads at *f*, and passing through the last thirling made there, returns to the opposite side of the double doors, ascends now the heading *g* to the foreheads at *h*, passes through the last-made thirling at that point, and descends, in the heading *i*, till it is interrupted by the double doors at *k*. The aërial current now moves along the heading *l*, to the foreheads at *m*, returns by the last-made thirling there, along the heading *n*, and finally goes down the heading *o*, and mounts by the upcast shaft *a*, carrying with it all the noxious gases which it encountered during its circuitous journey. This woodcut is a faithful representation of the system by which collieries of the greatest extent are worked and ventilated. In some of these the air courses are from 30 to 40 miles long. Thus the air conducted by the medium of a shaft divided by a brattice-wall only a few inches thick, after descending in the downcast in one compartment of the pit at 6 o'clock in the morning, must thence travel through a circuit of nearly 30 miles, and cannot arrive at its reascending compartment on the other side of the brattice, or pit partition, till 6 o'clock in the evening, supposing it to move all the time at the rate of $2\frac{1}{2}$ miles per hour. Hence we see that the *primum mobile* of this mighty circulation, the furnace, must be carefully looked after, since its irregularities may affect the comfort, or even the existence of hundreds of miners spread over these vast subterraneous labyrinths. On the principles just laid down, it appears, that if any number of boards be set off from any side of these galleries, either in a level, dip, or rise direction, the circulation of air may be advanced to each forehead by an ingoing and returning current.

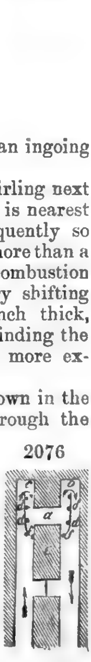
2075



Yet while the circulation of fresh air is thus advanced to the last-made thirling next the foreheads *f, h,* and *m*, *fig.* 2075, and moves through the thirling which is nearest to the face of every board and room, the emission of fire-damp is frequently so abundant from the coaly strata, that the miners dare not proceed forwards more than a few feet from that aërial circulation, without hazard of being burned by the combustion of the gas at their candles. To guard against this accident, temporary shifting brattices are employed. These are formed of deal, about $\frac{3}{4}$ of an inch thick, 3 or 4 feet broad, and 10 feet long; and are furnished with cross-bars for binding the deals together, and a few finger-loops cut through them, for lifting them more expeditiously, in order to place them in a proper position.

The mode of applying these temporary brattices, or deal partitions, is shown in the accompanying figure (2076), which shows how the air circulates freely through the thirling *d, d,* before the brattices are placed. At *b* and *c*, we see two heading boards or rooms, which are so full of inflammable air as to be unworkable. Props are now erected near the upper end of the pillar *e*, betwixt the roof and pavement, about 2 feet clear of the sides of the next pillar, leaving room for the miner to pass along between the pillar side and the brattice. The brattices are then fastened with nails to the props, the lower edge of the under brattice resting on the pavement, while the upper edge of the upper is in contact with the roof. By this means any variation of the height in the bed of coal is compensated by the overlap of the brattice boards; and as these are advanced, shifting brattices are laid close to and alongside of the first set. The miner next sets up additional props in the same parallel line with the former, and slides the brattices forwards to make the air circulate close to the forehead where he is working; and he regulates the distance betwixt the brattice and the forehead by the disengagement of fire-damp and the velocity of the aërial circulation. The props are shown at *d d*, and the brattices at *f f*. By this arrangement the air is pre-

2076

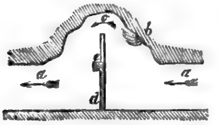


vented from passing directly through the thirling *a*, and is forced along the right-hand side of the brattice, and, sweeping over the wall face or forehead, returns by the back of the brattice, and passes through the thirling *a*. It is prevented, however, from returning in its former direction by the brattice planted in the forehead *c*, whereby it mounts up and accomplishes its return close to that forehead. Thus headways and boards are ventilated till another thirling is made at the upper part of the pillar. The thirling *a* is then closed by a brick stopping, and the brattice-boards removed forward for a similar operation.

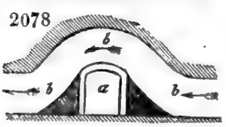
When blowers occur in the roof, and force the strata down, so as to produce a large vaulted excavation, the accumulated gas must be swept away; because, after filling that space, it would descend in an unmixed state under the common roof of the coal. The manner of removing it is represented in *fig.* 2077, where *a* is the bed of coal, *b* the blower, *c* the excavation left by the downfall of the roof, *d* is a passing door, and *e* a brattice. By this arrangement the aërial current is carried close to the roof, and constantly sweeps off or dilutes the inflammable gas of the blower, as fast as it issues. The arrows show the direction of the current; but for which, the accumulating gas would be mixed in explosive proportions with the atmospheric air, and destroy the miners.

There is another modification of the ventilating system, where the air-courses are traversed across; that is, when one air-course is advanced at right angles to another, and must pass it in order to ventilate the workings on the farther side. This is accomplished on the plan shown in *fig.* 2078, where *a* is a main road with an air-course, over which the other air-course *b*, has to pass. The sides of this air-channel are built of bricks arched over, so as to be air-tight, and a gallery is driven in the roof strata as shown in the figure. If an air-course, as *a*, be laid over with planks made air-tight, crossing and recrossing may be effected with facility. The general velocity of the air in these ventilating channels is from 3 to 4 feet per second, or about 2½ miles per hour, and their internal dimensions vary from 5 to 6 feet square, affording an area of from 25 to 36 square feet.

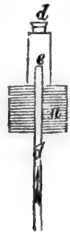
2077



2078



2079



The hydraulic air-pump deserves to be noticed among the various ingenious contrivances for ventilating mines, particularly when they are of moderate extent. *a* is a large wooden tub, nearly filled with water, through whose bottom the ventilating pipe *b* passes down into the recesses of the mine. Upon the top of *b* there is a valve *e*, opening upwards. Over *b*, the gasometer vessel is inverted in *a*, having a valve also opening outwards at *d*. When this vessel is depressed by any moving force the air contained within it is expelled through *d*; and when it is raised, it diminishes the atmospherical pressure in the pipe *b*, and thus draws air out of the mine into the gasometer; which cannot return on account of the valve at *e*, but is thrown out into the atmosphere through *d* at the next descent.

Struve's Mine Ventilator.—This ventilator has been constructed in some of the mines of South Wales upon a very large scale. Although in principle a pump of the simplest form, some of the pistons have been made 20 feet in diameter, and two pumps were constructed 21 feet in diameter. See *fig.* 2080.

In some mines to which the machine has been applied, the rarefaction and ventilation has proved so strong as to prevent single doors being opened, unless protected by supplemental doors. The circumstance of the air not being compressed in the machine admits of large valve spaces, so that there is scarcely any appreciable resistance to the passage of the air through the machine.

The annexed drawing, *fig.* 2080, represents the machine in operation at the Governor and Company's large collieries at Cwm Avon, Glamorganshire.

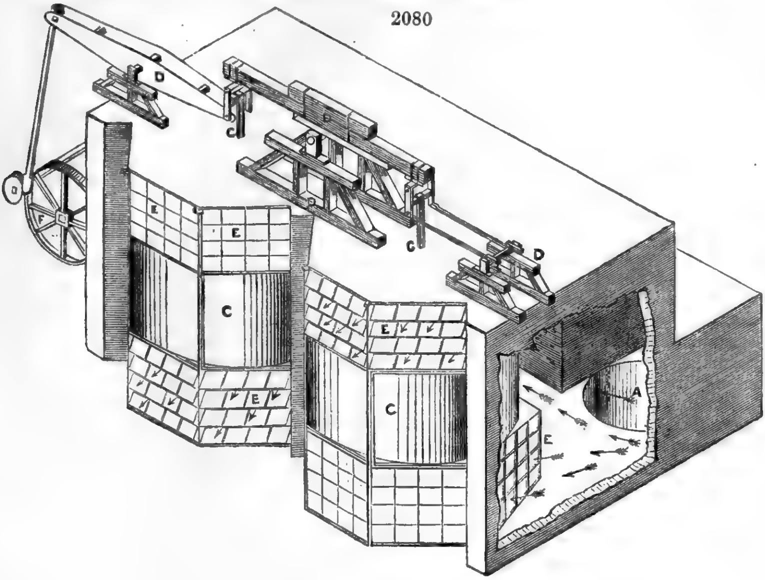
The sectional view explains the internal construction, the darts showing the air-currents ascending the upcast pit A, from the interior of the mine into the machine.

The general plan of distributing the air in all cases is to send the first of the current that descends in the downcast shaft among the horses in the stables, next among the workmen in the foreheads, after which the air, loaded with whatever mixtures it may have received, is made to traverse the old wastes. It then passes through the furnace with all the inflammable gas it has collected, ascends the upcast shaft, and is dispersed into the atmosphere. This system, styled *coursing the air*, was invented by Mr. Spedding of Cumberland.

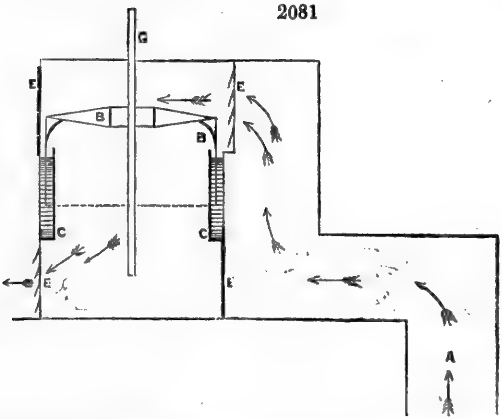
The piston B, is shown immersed in water, which forms an air-tight packing.

The front or outlet valves E, are shown in the external view of the ventilator. The end of the machine is represented open in the drawing, for the convenience of showing the inlet valves E, and of explaining the internal construction.

2080



2081



A. The upcast pit.
B. Hollow pistons, made of wrought iron.
C. Wrought-iron tanks, resting on two blocks of masonry, and on six iron pillars.
D. Beam work, resting on three blocks of masonry.
E. The valve work and framing, fastened to sixteen upright pieces of timber, 9 inches square.
F. Crank-wheel of steam-engine.
G. Piston-rods.

In ventilating the very thick coal of Staffordshire, though there is much inflammable gas, less care is needed than in the North-of England collieries, as the workings are very roomy, and the air-courses of comparatively small extent. The air is conducted down one shaft, carried along the main roads, and distributed into the sides of work. A narrow gallery, termed 'the air-head,' is carried in the upper part of the coal, in the rib walls, along one or more of the sides. Lateral openings, named 'spouts,' are led from the air-head gallery into the side of the work; and the circulating stream, mixed with the gas in the workings, enters by these spouts, and returns by the air-head to the upcast pit.

The means adopted in the South Staffordshire coal-mines, which have seams varying from 25 to 30 feet in thickness, are well worthy of consideration; since a solid mass of that magnitude must be peculiarly difficult to drain of its imprisoned gas. In excavating such coal large masses must be detached, and pockets or hollows must be formed, which are immediately filled with carburetted hydrogen; whilst a thin vein, for which a level roof can be generally secured, can be kept tolerably free from such accumulations.

According to the ordinary system adopted in the collieries of the South Staffordshire district, two shafts are sunk, near together, about 7 to 7½ feet in diameter, each to the bottom of the coal, say about 180 yards depth, the two shafts commencing at the same level, and terminating at the same level. One of these becomes the 'downcast pit' down which the air descends, and the other the 'upcast pit' up which the air ascends, when a communication is made between them at the bottom; but the only determining causes for the motion of the air being accidental, it is unknown beforehand what direction the current will take, and which will become the downcast pit. It is always found that a current of air does take place without any other means being employed; but the determining power is so faint, that, issuing from the upcast pit with such trifling velocity, it is liable to be deranged by the action of the wind, or by atmospheric changes; and it sometimes happens that the air becomes quiescent, or an unsteady column, alternately ascending and descending the same shaft; and then, in miner's language, the pits 'fight,' and the air will neither ascend nor descend with regularity in one direction.

When the two pits are sunk down through the stratum of coal 30 ft. in thickness, a 'gate-road' or horse-way is next driven in the bottom of the coal, from 8 to 9 ft. high, and about the same width, commencing from the bottom of the downcast pit.

At the same time an air-head is driven about the middle of the coal, or 15 feet high from the 'floor' or the bottom of the coal, commencing from the downcast pit. The gate-road and air-head are then driven in parallel lines, at the same level upon which they commence, for the distance of 100 to 500 yards, or more, according to the quantity of coal intended to be cleared by the pits.

A series of 'spouts' or openings are driven upwards from the gate-road into the air-head, at intervals of 10 or 15 yards to carry off the gas formed, and produce a current of air for the workmen,—each spout being closed up when a new one is made in advance. The excavation of the whole thickness of the stratum of coal, 30 feet thick, is then proceeded with, by opening right and left from the end of the gate-road, and excavating a 'side of work,' which forms a rectangular cavity, say about 90 yards long by 50 yards wide, or about an acre, the whole of the coal being taken away as far as practicable, excepting the pillars of coal (generally 10 yards square and 10 yards distant from each other) which are left to support the superincumbent strata.

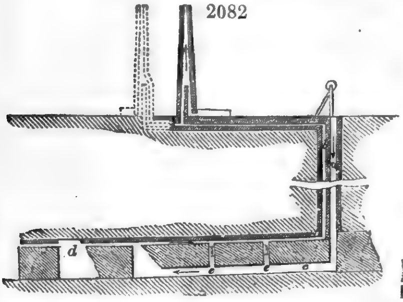
The air descending the downcast pit, and travelling along the gate-road into the workings, ascends to the air-head, and traversing that, ascends the upcast pit, carrying with it the gas and impure vapours, as far as such imperfect and interrupted means will effect, and delivering them into the open air.

By this plan the mine is ventilated, until the lower 15 feet of the coal is excavated; but where the whole thickness of the coal above the air-head has been removed, by undergoing the coal from the bottom, and dropping it down in large masses, the upper portion of the cavity, being above the level of the air-head, forms a reservoir for gas, which gradually accumulates, and has no means of escape,—a reservoir of the capacity of some hundred thousand of cubic feet, which may be wholly or in part occupied by gas. An accidental change in the direction of the current of air would turn the course of the air along the air-head into this reservoir of gas, and from thence into the gate-road, and render an explosion very probable. After the coal is extracted, a solid wall or 'rib' of coal, from 6 to 10 yards thick, which is commonly termed a 'fire-rib,' is left all round the chamber, separating it from the next workings; and the entrance from the gate-road is securely walled up, to exclude the air, and prevent spontaneous combustion, which would otherwise, in a short period, take place. When an explosion occurs, it is generally followed by a second, or more, as portions of the gas become successively charged with the due proportions of air; and the liability to these terrible explosions will always remain in mines thus worked, till, by some efficient means, the gas can be allowed a continuous escape, and a current of air can be ensured to move always in one direction, with sufficient power to overcome all extraneous disturbing forces, either of the wind or any atmospheric changes.

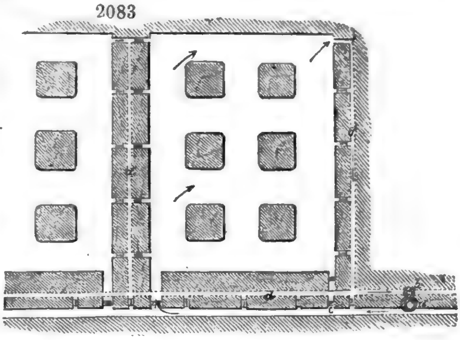
In *fig.* 2082 the system adopted and carried into operation by the late Benjamin Gibbons is shown. One pit *a*, is sunk, instead of two; and in the side of the shaft a smaller shaft *b* is cut, to form an 'air-chimney,' and is afterwards separated from the main shaft; this air-chimney is circular, and may be made about three feet diameter inside, or more, as may be required. The air-chimney is bricked at the same time with the shaft,—the circular brickwork of each forming a partition of double thickness and secure strength, from the two arches abutting against each other.

The gate-road *c*, is driven from the shaft at the bottom of the coal, as in the ordinary plan; but the air-head *d* is driven from the air-chimney within 2 feet of the top of the coal, or higher, if practicable, and runs into the vertical air-chimney. The gate-road and air-head are carried forward in a parallel direction to the extent of the work, as before described in the ordinary system; and 'spouts' or openings, *c*, are driven upwards to connect them, at about every 15 yards—every spout being bricked up close, in succession, when a fresh one is made in advance, so as to make the current of air traverse the whole extent of the gate-road before it rises up to the air-head and passes away to the air-chimney.

2082



2083



In the ordinary system of ventilation, it is manifest that only a very slight determining power compels the air to travel constantly in the same direction. Its current is, at all times, weak and insufficient, and liable to be deranged by the action of the wind, or atmospheric changes; and it is under no command whatever. To ensure safety a constant current of air is indispensably necessary; it should be a current, too, maintained by natural causes, as far as possible, and never interrupted, for the reasons already assigned; and should be one that would not vary or fail.

To effect this, the ascending column of air must be rendered specifically lighter than the air of the descending column, which circulates through the workings; and this difference of specific gravity must be maintained constantly free from disturbance by accidental causes, and to such an extent as to produce under all circumstances a total amount of propelling power that is found sufficient for the complete ventilation of the mine. This is accomplished by conducting the whole of the gas in a continuous ascending column, free from interruption or disturbance, up the separate air-chimney; and this ascending power is further increased by erecting a ventilating chimney (shown by dots in the vertical section), of a sufficient height, on the surface of the ground, into the base of the air-chimney is continued so as to form one uninterrupted air-flue, from the top of the ventilating chimney down to the air-head in the seam of coal.

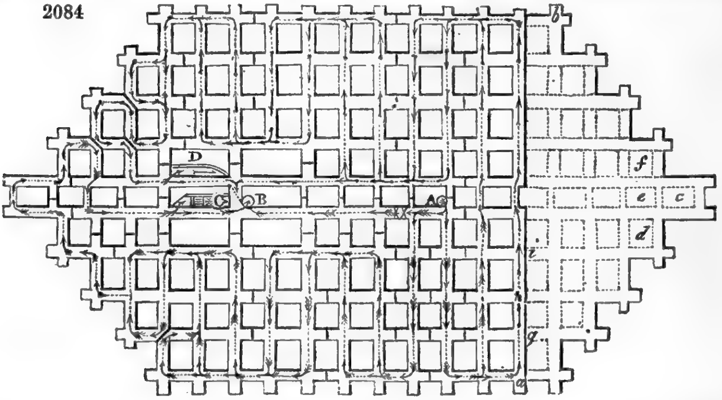
Ventilation is nowhere exhibited to such advantage as in the coal-mines of Northumberland and Durham, where they have carried well nigh to systematic perfection the plan of coursing the air through the winding galleries.

In Mr. Spedding's system the whole of the return air came in one current to his rarefying furnace (see letter c, *fig.* 2084), whether it was at the explosive point or not. This distribution was often fraught with such danger, that a torrent of water had to be kept in readiness, under the name of 'the waterfall,' to be let down to extinguish the fire in a moment. Many explosions at that time occurred, from the furnaces below, and also down through tubes from the furnaces above ground.

About the year 1807 Mr. Buddle had his attention intensely occupied with this most important object, and then devised his plan of a divided current, carrying that portion of the air which, descending in the downcast pit A, coursed through the *clean* workings, through the active furnace C, *fig.* 2084, and the portion of the air from the *foul* workings up the dumb furnace D, till it reached a certain elevation in B, the upcast pit, above the fireplace. The pitmen had a great aversion, however, at first to adopt this plan, as they thought that the current of air by being split would lose its ventilating power; but they were ere long convinced by Mr. Buddle to the contrary. He divided the main current into two separate streams, at the bottom of the pit A, as shown by darts in the figure; the feathered ones representing that part of the pit in which the course of the current of air is free from explosive mixture, or does not contain above one-thirtieth of carburetted hydrogen, as indicated by its effect upon the flame of a candle. The naked darts denote the portions of the mine where the air, being charged to the firing-point, is led off towards D, the dumb furnace, which communicates with the hot upcast shaft, out of reach of the flame, and thence derives its power of draught. By suitable alterations in the stoppings (see the various transverse lines, and the crosses) any portion of the workings may, by the agency of the furnace, be laid out of, or brought within, the course of the vitiated current, at the pleasure of the skilful mine-viewer; so that, if he found it necessary, he could confine, by proper arrangements of his furnace, all the vitiated currents to a mere gas-pipe or drift, and direct it wholly through the dumb furnace. During a practice of twenty years Mr. Buddle had not met with any accident in consequence of a defect in the stoppings preventing the complete division of the air. The engineer has it thus within his power to detach or insulate those portions of the mine in which there is a great exudation of gas, from the rest; and, indeed, he is continually making changes, borrowing and lending currents, so to speak; sometimes laying one division or panel upon the one air-course, and sometimes upon the other, just to suit the immediate emergency. As soon as any district has ceased to be dangerous, by the exhaustion of the gas-blowers, it is transferred from the foul to the pure air-course, where gunpowder may be safely used, as also candles, instead of Davy's lamps, which give less light.

Till the cutting out of the pillars commences (see the right end of the diagram), the ventilation of the several passages, boards, &c., may be kept perfect, supposing the working, extending no farther than *a* or *b*; because, as long as there are pillars standing, every passage may be converted into an air-conduit, for leading a current of air in any direction, either to C, the burning, or D, the dumb furnace. But the first pillar that is removed deranges the ventilation at that spot, and takes away the means of carrying the air in the further recess towards *c*. In taking out the pillars, the miners always work to windward, that is to say, against the stream of air; so that whatever gas may be evolved shall be immediately carried off from the people at work. When a range of pillars has been removed, as at *d*, *e*, *f*, no power remains of dislodging the gas from the section of the mine beyond *a*, *b*; and as the pillars are successively cut away to the left hand of the line *ab*, *b*, the size of the *goaf*, or void, is increased. This vacuity, or goaf, is a true gas-holder, or reservoir, continually discharging itself at the points *g*, *h*, *i*, into the circulating current, to be carried off by the gas-pipe drift at the dumb furnace, but not to be suffered ever to come in contact with flame of any description. The next range of working is the line of pillars to the left of *a*, *b*; the coal having been entirely cleared out of the space to the right, where the place of the pillars is marked by dotted lines. The roof in the waste soon falls down, and gets fractured up to the next seam of coal, which, abounding in gas, sends it down in large quantities, and keeps the goaf below continually replenished.

2084

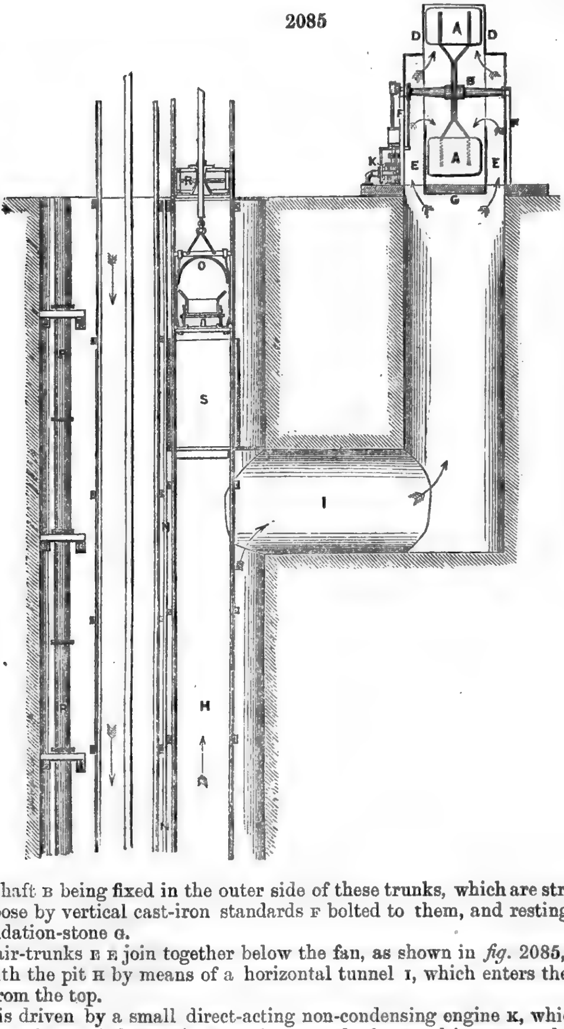


Description of the Ventilating Fan at the Abercarn Collieries.—The late Mr. E. Rogers having occasion to ventilate the workings in some extensive and very fiery coal-seams won at Abercarn in South Wales, under circumstances where the furnace-ventilation could not be applied, came to the conclusion that a plan of machine proposed for the purpose by Mr. James Nasmyth would be the most suitable and effective. After consultation with Mr. Nasmyth, it was resolved to test the principle and plan by actual practice; and the ventilating fan described was erected at the Abercarn Collieries.

The general arrangements of the top of the shaft and the ventilating fan are shown in *figs.* 2085 and 2086. *Fig.* 2087 is a side elevation of the fan and engine, to a larger scale; and *fig.* 2086 a vertical section of the fan.

The fan A A, *fig.* 2087, is 13½ feet diameter, with 8 vanes, each 3 feet 6 inches wide and 3 feet long. It is fixed on a horizontal shaft B, 8 feet 7 inches in length from centre to centre of its bearings, which are nine inches long by 4½ inches diameter. The vanes are of thin-plate iron, and carried by forked wrought-iron arms secured to a centre disk C, fixed upon the shaft B. The fan works within a casing, D D, consisting of two fixed sides of thin wrought plate, entirely open round the circumference and connected together by stay-rods; the sides are 3 inches clear from the edges of the vanes, and have a circular opening 6 feet diameter in the centre of each, from which rectangular wrought-iron trunks, E E, are carried down for the entrance of the air, the bearings for the fan-shaft B being fixed in the outer side of these trunks, which are strengthened for the purpose by vertical cast-iron standards F bolted to them, and resting upon the bottom foundation-stone G.

2085

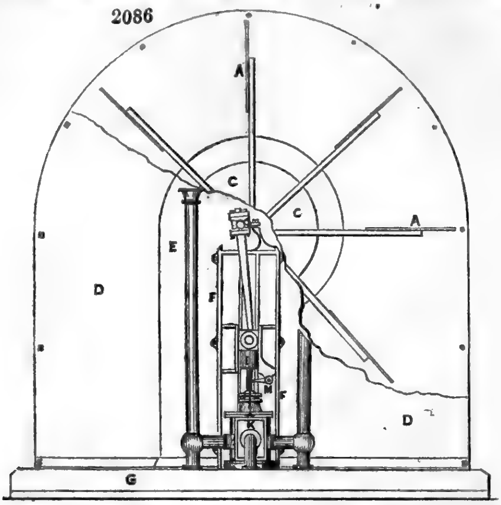


The two air-trunks E E join together below the fan, as shown in *fig.* 2085, and communicate with the pit H by means of a horizontal tunnel I, which enters the pit at 21 feet depth from the top.

The fan is driven by a small direct-acting non-condensing engine K, which is fixed upon the face of one of the vertical cast-iron standards F, and is connected to a crank on the end of the fan-shaft B. The steam-cylinder is 12 inches diameter and 12 inches stroke, and is worked by steam from the boilers of the winding engine of the pit, at a pressure of about 13 lbs. per square inch. The excentric L for the slide valve is placed just inside the air-trunk E, and works the valve through a short-weight shaft M, with a lever on the outside.

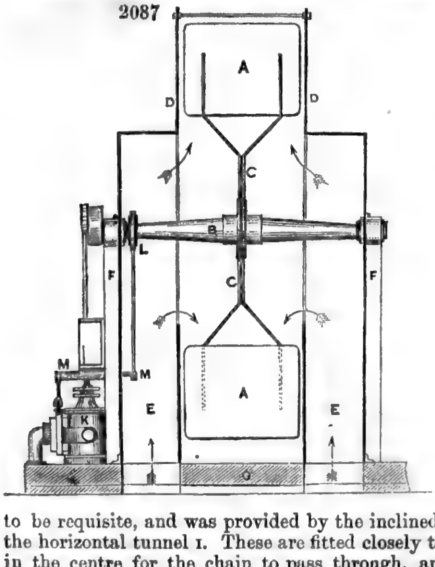
The pit H, *fig.* 2085, is of an oval form, 10 feet by 18 feet, and divided near the centre by a timber brattice N, the one side forming the upcast shaft and the other the downcast. Both of these are used for winding, and the cages O, in which the trucks, &c., are brought up, work between guides fixed to the timbering of the pit. The pumps P are placed in the downcast shaft.

2086



In order to allow of the upcast shaft being used for winding, the top is closed by an air-valve R, which is formed by simply boarding up the underside of the ordinary guard upon the mouth of the shaft, leaving only the hole in the centre through which the chain works. This air-valve R is carried up by the cage O on arriving at the top of the shaft, as in *fig.* 2085, and then drops down again flat upon the opening when the cage is again lowered. During the time that the valve is lifted, its place is occupied by the close bottom of the cage O, which nearly fills the rectangular opening left at the top of the shaft. By this simple means it is found practically that a complete provision is made for keeping the top of the upcast shaft closed, and maintaining a uniform current of air up the shaft; for the leakage of air downwards through the top whilst the cage is in the act of opening or closing the air-valve, and through the small area that always remains open, is found to be quite immaterial, and the surplus ventilating power of the fan is amply sufficient to provide against it.

2087



In the original construction a more perfect air-valve was supposed to be requisite, and was provided by the inclined flaps S S, which are fixed just above the horizontal tunnel I. These are fitted closely together, leaving only a small opening in the centre for the chain to pass through, and were intended to be opened by the ascending cage coming in contact with them, closing again directly by means of balance weights before the air-valve R at the top of the shaft was opened, so as to preserve a thorough closing of the top of the shaft. The flaps were to be opened again by a lever from the top to allow the cage to descend. However, it was found on trial that the valve R at the top was amply sufficient; and consequently, although the other valves were also provided, they were never put into use.

The total depth of the pit is nearly 300 yards, and at a depth of 120 yards a split of air is taken off, and coursed through workings from which coal and fire-clay are got; the larger portion of the air descends to the bottom of the pit, and is there split into many courses, to work two separate seams of coal and a vein of ironstone. The total length of road laid with plates or rails in the workings is about 7 miles, and the working faces amount to nearly double that distance. The longest distance that is traversed by any single course or split of air in passing from the downcast to the upcast shaft is nearly 2 miles. The quantity of materials raised from the pit is about 500 tons daily.

The following Table gives the results of a series of experiments made with this ventilating fan by Mr. R. S. Roper, showing that the quantity of air delivered at the velocities of 60 and 80 revolutions of the fan per minute is 45,000 and 56,000 cubic feet per minute, with a velocity of current of 782 and 1,037 lineal feet per minute respectively, or about 9 and 12 miles per hour; and the degree of vacuum or exhaustion in the upcast shaft is ·5 and ·9 inch of water respectively.

Synopsis of Experiments on Fan Ventilation.

	Height of barometer		Temperature by Fahrenheit's thermometer				Revolutions of fan per minute	Water-gauge	Velocity of air in feet per minute	Cubic feet of air per minute	Steam-gauge on fan	Theoretical consumption of coal per hour
	At the surface	At the bottom	Top of downcast	Bottom of downcast	Bottom of upcast	10 yards from top of upcast						
	ins.	ins.	deg.	deg.	deg.	deg.		ins.			lbs.	lbs.
Mean of twelve experiments, Natural Ventilation . . .	29·61	30·60	41·10	51·73	55·56	48·00	..	·15	446·0	24·325	..	..
Mean of four experiments, Fan Ventilation	29·85	30·85	38·10	50·10	53·93	47·30	60	·50	781·8	45·187	13·0	17·4
Mean of five experiments, Fan Ventilation	29·65	30·61	41·40	50·70	55·10	48·70	80	·90	1037·0	56·555	19·3	23·2

The speed at which the ventilating fan is usually worked is about 60 revolutions per minute, giving a velocity at the circumference of the fan of 2,545 feet per minute; 45,000 cubic feet of air per minute are then drawn through the mine, nearly one-third of which ventilates the upper workings, and the rest passes through the lower workings.

The Guibal fan especially has been used in several collieries.

Several modified forms of fan ventilation have been introduced, but the principle involved is essentially the same in all.

VERANTINE. See MADDER.

VERATRINE. $C^{64}H^{52}N^{2}O^{16}$ (**$C^{32}H^{52}N^{2}O^{8}$**). An alkaloïd contained in white hellebore (*Veratrum album*), and in cevadilla (*V. Sabadilla*). It is exceedingly poisonous, and if introduced into the nostrils excites violent and prolonged sneezing. In the form of ointment it has been found a valuable remedy in neuralgic disorders.

VERDIGRIS. (*Vert-de-gris*, Fr.; *Grünspan*, Ger.) The copper used in this manufacture is formed into round sheets, from 20 to 25 inches diameter, by one-twenty-fourth of an inch in thickness. Each sheet is then divided into oblong squares, from 4 to 6 inches in length, by 3 broad; and weighing about 4 ounces. They are separately beaten upon an anvil, to smooth their surfaces, to consolidate the metal, and to free it from scales. The refuse of the grapes, after the extraction of their juice, formerly thrown on to the dunghill, is now preserved for the purpose of making verdigris. It is put loosely into earthen vessels, which are usually 16 inches high, 14 in diameter at the widest part, and about 12 at the mouth. The vessels are then covered with lids, which are surrounded by straw mats. In this situation the materials soon become heated, and exhale an acid odour; the fermentation beginning at the bottom of the cask, and gradually rising till it actuates the whole mass. At the end of two or three days the manufacturer removes the fermenting materials into other vessels, in order to check the process, lest putrefaction should ensue. The copper-plates, if new, are now prepared, by rubbing them over with a linen cloth, dipped in a solution of verdigris; and they are laid up alongside of one another to dry. If the plates are not subjected to this kind of preparation they will become black, instead of green, by the first operation. When the plates are ready, and the materials in a fermenting state, one of them is put into the earthen vessel for 24 hours, in order to ascertain whether it be a proper period to proceed to the remaining part of the process. If, at the end of this period, the plate be covered with an uniform green layer, concealing the whole copper, everything is right; but if, on the contrary, liquid drops hang on the surface of the metal, the workmen say the plates are *sweating*, and conclude that the heat of the fermented mass has been inadequate; on which account another day is allowed to pass before making a similar trial. When the materials are finally found to be ready, the strata are formed in the following manner:—The plates are laid on a horizontal wooden grating, fixed in the middle of a vat, on whose bottom a pan full of burning charcoal is placed, which heats them to such a degree that the women who manage this work are obliged to lay hold of them frequently with a cloth when they lift them out. They are in this state put into earthen vessels, in alternate strata with the fermented materials, the uppermost and undermost layers being composed of the expressed grapes. The vessels are covered with their straw mats, and left at rest. From 30 to 40 lbs. of copper are put into one vessel.

At the end of 10, 12, 15, or 20 days the vessels are opened to ascertain, by the materials having become white, if the operation be completed.

Detached glossy crystals will be perceived on the surface of the plates; in which case the grapes are thrown away, and the plates are placed upright in a corner of the verdigris cellar, one against the other, upon pieces of wood laid on the ground. At the end of two or three days they are moistened by dipping in a vessel of water, after which they are replaced in their former situation, where they remain seven or eight days, and are then subjected to momentary immersion, as before. This alternate moistening and exposure to air is performed six or eight times, at regular intervals of about a week. As these plates are sometimes dipped into damaged wine, the workmen term these immersions *one wine, two wines*, &c.

By this treatment the plates swell, become green, and covered with a stratum of verdigris, which is readily scraped off with a knife. At each operation every vessel yields from 5 to 6 lbs. of verdigris, in a *fresh* or *humid* state; which is sold to wholesale dealers, who dry it for exportation. For this purpose they knead the paste in wooden troughs, and then transfer it to leathern bags, a foot and a half long and ten inches in diameter. These bags are exposed to the sun and air till the verdigris has attained a sufficient degree of hardness. It loses about half its weight in this operation; and it is said to be knife-proof when this instrument, plunged through the leathern bag, cannot penetrate the loaf of verdigris.

Verdigris is a mixture of the crystallised acetate of copper and the subacetate, in varying proportions. According to Vauquelin's researches, there are three compounds of oxide of copper and acetic acid: 1, a subacetate, insoluble in water, but decomposing in that fluid, at common temperatures changing into peroxide and acetate; 2, a neutral acetate, the solution of which is not altered at common temperatures, but is decomposed by ebullition, becoming peroxide and superacetate; and 3, superacetate, which in solution is not decomposed, either at common temperatures or at the boiling point; and which cannot be obtained in crystals, except by slow spontaneous evaporation, in air or *in vacuo*. The first salt, in the dry state, contains 66·51 of oxide; the second, 44·44; and the third, 33·34.

Distilled Verdigris, as it was long erroneously called, is merely a *binacetate* or superacetate of copper, made by dissolving, in a copper kettle, one part of verdigris in two of distilled vinegar; aiding the mutual action by slight heat and agitation with a wooden spatula. When the liquor has taken its utmost depth of colour, it is allowed to settle, and the clear portion is decanted off into well-glazed earthen vessels. Fresh vinegar is poured on the residuum, and if its colour does not become deep enough, more verdigris is added. The clear and saturated solution is then slowly evaporated, in a vessel kept uniformly filled, till it acquires the consistency of syrup, and shows a pellicle on its surface; when it is transferred into glazed earthen pans, called *oulas* in the country. In each of these dishes two or three sticks are placed, about a foot long, cleft till within two inches of their upper end, and having the base of the cleft kept asunder by a bit of wood. This kind of pyramid is suspended by its summit in the liquid. All these vessels are transported into crystallising rooms, moderately heated with a stove, and left in the same state for 15 days, taking care to maintain an uniform temperature. Thus are obtained very fine groups of crystals of acetate of copper, clustered round the wooden rods; on which they are dried, taken off, and sent into the market. They are distinctly rhomboïdal in form, and of a lively deep blue colour.

Each cluster of crystals weighs from five to six pounds; and, in general, their total weight is equal to about one-third of the verdigris employed.

VERDINE. One of the aniline colours, prepared by M. Eusebi.

VERDITER, or *Bremen Green.* This pigment is a light powder, having a blue or bluish-green colour. The first is most esteemed. When worked up with oil or glue, it resists the air very well.

The following is, according to M. J. G. Gentele, the process of fabrication in Bremen, Cassel, Eisenach, Minden, &c.:—225 lbs. of sea salt, and 222 lbs. of blue vitriol, both free from iron, are mixed in the dry state, and then reduced between mill-stones with water to a thick homogeneous paste. 225 lbs. of plates of old copper are cut by scissors into bits of an inch square, then thrown and agitated in a wooden tub containing 2 lbs. of sulphuric acid, diluted with a sufficient quantity of water, for the purpose of separating the impurities; they are afterwards washed with pure water in casks made to revolve upon their axes. The bits of copper being placed in oxidation-chests, along with the magma of common salt and blue vitriol previously prepared in strata of half an inch thick, they are left for some time to their mutual reaction. The above chests are made of oaken planks joined without iron nails, and set aside in a cellar, or other place of moderate temperature. The saline mixture, which is partially converted into sulphate of soda and chloride of copper, absorbs oxygen from the air, whereby the metallic copper passes into a hydrated oxide, with a rapidity proportioned to the extent of the surfaces exposed to the atmosphere. During the three months that the process requires, the whole mass must be turned over once every week, with a copper shovel, transferring it into an empty chest alongside, and then back into the former one. At the end of three months the corroded copper scales must be picked out, and the saline particles separated from the slimy oxide with the help of as little water as possible. This oxidised *Schalmm* or mud is filtered, then thrown by means of a bucket containing 30 lbs., in a tub, where it is carefully divided or comminuted. For every six pailfuls of *schalmm* thus thrown into the large tub, 12 lbs. of muriatic acid, at 15° Beaumé, are to be added; the mixture is to be stirred, and then left at rest for twenty-four or thirty-six hours. Into another tub, called the 'blue black,' there is to be introduced, in like manner, for every six pailfuls of the acidified *schalmm,* fifteen similar pailfuls of a solution of colourless clear caustic alkali, at 19° Beaumé. When the back has remained long enough at rest, there is to be poured into it a pailful of pure water for every pailful of *schalmm.* When all is thus prepared, the set of workmen who are to empty the back, and those who are to stir, must be placed alongside of each. The first set transfer the *schalmm* rapidly into the latter back, where the second set mix and agitate it all the time requisite to convert the mass into a consistent state, and then leave it at rest from thirty-six to forty-eight hours. The whole mass is to be now washed; with which view it is to be stirred about with the affusion of water, allowed to settle, and the supernatant liquor is drawn off. This process is to be repeated till no more traces of potash remain among the blue. The deposit must be then thrown upon a filter, where it is to be kept moist, and exposed freely to the air. The pigment is now squeezed in the filter-bags, cut into bits, and dried in the atmosphere, or at a temperature not exceeding 78° Fahr. It is only after the most complete desiccation that the colour acquires its greatest lustre.

VERDITER, BLUE. This is a precipitate of oxide of copper with lime, made by adding that earth, in its purest state, to the solution of nitrate of copper, obtained in quantities by the refiners, in parting gold and silver from copper by nitric acid. The cupreous precipitate must be triturated with lime, after it is nearly dry, to bring out the fine velvety blue colour. The process is delicate.

The *Cendres bleues en pâte* of the French, though analogous, are in some respects a different preparation. To make it, dissolve sulphate of copper in hot water, in such proportions that the liquid may have a density of 1·3. Take 240 pound measures of this solution, and divide it equally into four open-headed casks; add to each of these 45 pound measures of a boiling-hot solution of muriate of lime, of spec. grav. 1·317, whereby a double decomposition will ensue, with the formation of muriate of copper and sulphate of lime, which precipitates. It is of consequence to work the materials well together at the moment of mixture, to prevent the precipitate agglomerating in unequal masses. After leaving it to settle for 12 hours, a small quantity of the clear liquor may be examined, to see whether the just proportions of the two salts have been employed, which is done by adding either sulphate of copper or muriate of lime. Should either cause much precipitation, some of the other must be poured in till the equivalent decomposition be accomplished; though less harm results from an excess of sulphate of copper than of muriate of lime.

The muriate of copper is to be decanted from the subsided gypsum, which must be drained and washed in a filter; and these blue liquors are to be added to the stronger; and the whole distributed as before, into four casks; composing in all 670 pound measures of a green liquor, of 1·151 spec. grav.

Meanwhile, a magma of lime is to be prepared as follows:—100 lbs. of quicklime are to be mixed up with 300 lbs. of water, and the mixture is to be passed through a wire-gauze sieve, to separate the stony and sandy particles, and then to be ground in a proper mill to an impalpable paste. About 70 or 80 lbs. of this mixture (the beauty of the colour is inversely as the quantity of lime) are to be distributed in equal portions between the four casks, strongly stirring all the time with a wooden spatula. It is then left to settle, and the limpid liquor is tested by ammonia, which ought to occasion only a faint blue tinge: but if the colour be deep blue, more of the lime-paste must be added. The precipitate is now to be washed by decantation, employing for this purpose the weak washings of a former operation; and it is lastly to be drained and washed on a cloth filter. The proportions of material prescribed above furnish from 500 to 540 lbs. of green paste.

Before making further use of this paste, the quantity of water present in it must be determined by drying 100 or 200 grains. If it contain 27 per cent. of dry matter, 12 lbs. of it may be put into a wooden bucket (and more or less in the ratio of 12 to 27 per cent.) capable of containing 17½ pints; a pound (measure) of the lime-paste is then to be rapidly mixed into it; immediately afterwards, 1¼ pint of a watery solution of the pearlash of commerce, of spec. grav. 1·114, previously prepared; and the whole mixture is to be well stirred, and immediately transferred to a colour-mill. The quicker this is done, the more beautiful is the shade.

VERJUICE. (*Verjus*, Fr.; *Agrest*, Ger.) A harsh kind of vinegar, containing much malic acid, made from the expressed juice of the wild crab apple.

VERMICELLI, a paste of wheat-flour, drawn out and dried in slender cylinders, more or less tortuous, like worms—whence the Italian name. The flour of Southern countries is best suited for its manufacture.

It may be made economically by the following prescription:—

Vermicelli, or Naples flour	21 lbs.
White potato-flour	14
Boiling-water	12
Total	47 lbs.

Affording 45 lbs. of dough and 30 of dry vermicelli.

VERMICULITES. A group of minerals resembling the chlorites, remarkable for their exfoliation before the blowpipe.

VERMILION, or *Cinnabar*, is a compound of mercury and sulphur in the proportion of 100 parts of the former to 16 of the latter, which occurs in nature as a common ore of quicksilver, and is prepared by the chemist as a pigment, under the name of Vermilion. It is, properly speaking, a bisulphide of mercury. This artificial compound being extensively employed, on account of the beauty of its colour, in painting, for making red sealing-wax, and other purposes, is the object of an important manufacture. When vermilion is prepared by means of sublimation, it concretes in masses of considerable thickness, concave on one side, convex on the other, of a needle-form texture; brownish-red in the lump, but when reduced to powder it is of a lively red colour. On exposure to a moderate heat, it evaporates without leaving a residuum, if it be not contaminated with red lead; and at a higher heat, it takes fire, and burns entirely away, with a blue flame.

The English vermilion is now most highly prized by the French manufacturers of sealing-wax.

The humid process of Kirchhoff has of late years been so much improved, as to furnish a vermilion quite equal in brilliancy to the Chinese. The following process has been recommended:—Mercury is triturated for several hours with sulphur, in the cold, till a perfect ethiops is formed; potash-lye is then added, and the trituration is continued for some time. The mixture is now heated in iron vessels, with constant stirring at first, but afterwards only from time to time. The temperature must be kept up as steadily as possible at 130° Fahr., adding fresh supplies of water as it evaporates. When the mixture, which was black, becomes, at the end of some hours, brown-red, the greatest caution is requisite to prevent the temperature from being raised above 114°, and to preserve the mixture quite liquid, while the compound of sulphur and mercury should always be pulverulent. The colour becomes red, and brightens in its hue, often with surprising rapidity. When the tint is nearly fine, the process should be continued at a gentler heat, during some hours. Finally, the vermilion is to be elutriated, in order to separate any particles of running mercury.

The three ingredients should be very pure. The proportion of product varies with that of the constituents, as we see from the following results of experiments, in which 300 parts of mercury were always employed, and from 400 to 450 of water:—

Sulphur	Potash	Vermilion obtained
114	75	330
115	75	331
120	120	321
150	152	382
120	180	245
100	180	244
60	180	142

VERT DE GUIGNET. See Mittler's Green.

VICUNA or **VICUGNA.** *Llama vicugna.* A variety of the Llama of South America.

VINE BLACK. A black procured by charring the tendrils of the vine and levigating them.

VINE DISEASE. *Oïdium Tuckeri.* The disease which has recently ravished the vines of the South of France is attributed to the *Phylloxera vastatrix.* See Wines.

VINEGAR. All liquids which are susceptible of the vinous fermentation are capable of yielding vinegar. A solution of sugar is the essential ingredient, which is converted first into alcohol, and subsequently into acetic acid. The liquids employed vary according to circumstances. In this country the vinegar of commerce is obtained from an infusion of malt, and in wine countries from inferior wines.

The oxidation of alcohol is remarkably facilitated by the presence of nitrogenised organic bodies in a state of change, called *ferments*; hence the process is frequently termed *acetous fermentation.* Now, although in most cases the presence of these ferments curiously promotes the process, yet they have no specific action of this kind; for we have already seen that, by exposure to air in a condensed state, alcohol, even when pure, is converted into acetic acid; and, moreover, the action of oxidising agents, such as chromic and nitric acid, &c., is capable of effecting this change.

However, in the presence of a ferment, with a free supply of air, and at a temperature of from 60° to 90° Fahr., alcohol is abundantly converted into acetic acid.

At the same time that the alcohol is converted into acetic acid, the nitrogenised and other organic matters undergo peculiar changes, and often a white gelatinous mass is deposited,—which contains *vibriones* and other of the lower forms of organised beings,—and which has received the name of *mother of vinegar,*[1] from the supposition that the formation and development of this body, instead of being a secondary result of the process, was really its exciting cause.

1. Wine Vinegar. (*Vinaigre,* Fr.; *Weinessig,* Ger.) Wine vinegar is made of the best quality, and on the greatest scale, at Orléans in France, out of wines which have become more or less acidulous, and are, therefore, of inferior value. When the vinegar is made from well-flavoured wines, it is preferable to every other for the use of the table. The old method pursued in the *vinaigreries* consists merely in partially filling a series of large casks placed in three or four ranges over each other, in a cellar warmed with a stove to the temperature of 85° Fahr., with the wine mixed with a certain proportion of ready-made vinegar as a ferment. Low-roofed apartments are the most suitable; when there is a high ceiling it is necessary to elevate the 'mothers,' in order that they may occupy the higher strata of warm air. This trouble is dispensed with when the roofs are low. Experience has proved that in high-roofed apartments, where the tuns are placed at different levels, the uppermost work off quicker and better than the others. More wine is added, in successive small portions, as fast as the first has become acetified, taking care that a free ventilation be maintained, in order to replace the carbonic acid produced by fresh atmospheric oxygen. In summer, under a favourable exposure of the windows and walls of the fermenting room to the sun, artificial heat is not needed. Each cask is of about 60 gallons' capacity, and into each cask of the set is poured ⅓rd its capacity of vinegar, to which 2 galls. of wine are added, and weekly, afterwards, 2 galls. more. About 8 galls. are drawn off at the end of four weeks as vinegar, and then successive additions of wine are made as before to the casks. These are laid horizontally in rows upon their gawntrees, and are pierced at the upper surface of the front end with two holes: one, called the *eye,* is two inches in diameter, and serves for pouring in the charges through a funnel; the other is a small air-hole alongside. The casks should never be more than ⅔rds full, otherwise a sufficient body of air is not present in them for favouring rapid acetification. At the end of a certain period, the deposit of tartar and lees becomes so great that the

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[1] This substance has been supposed by some to be a fungus, and has been described by Mulder under the name of *Mycoderma aceti,* or *vini.*

casks must be cleared out. This renovation usually takes place every 10 years; but the casks, when made of well-seasoned oak and bound with iron hoops, will last 25 years. The wine, as well the vinegar produced, should be clarified by being slowly filtered through beech-chips, closely packed in a large open tun. When wines are new, and somewhat saccharine or too alcoholic, they acetify reluctantly, and need the addition of a little yeast, or even water, to the mixture; and when they are too weak, they should be enriched by the addition of some sugar or stronger wine, so as to bring them to a uniform state for producing vinegar of normal strength. To favour the renewal of fresh air into the upper part of the hogsheads, it would be advisable to pierce a two-inch hole near to the upper level of the liquid when the cask is fullest, by which means the heavy carbonic acid would fall out, and be replaced by the atmospheric air at the superior apertures.

Wine vinegar is of two kinds, *white* and *red*, according as it is prepared from white or red wine. *White wine vinegar* is usually preferred, and that made at Orléans is regarded as the best.

Dr. Ure found its average specific gravity to be 1·019, and to contain from 6½ to 7 per cent. of real acid; according to the Edinburgh Pharmacopæia, its specific gravity varies from 1·014 to 1·022.

2. Malt Vinegar. (*British Vinegar*; in Germany called *Malz-Getreide-* or *Bier-essig.*) In England vinegar is chiefly made from an infusion of malt, by first exciting in it the alcoholic fermentation, and subsequently inducing the oxidation of the alcohol into acetic acid.

For details of the processes of *malting* and *brewing* the alcoholic liquor, we must refer to the special articles on these subjects, confining our attention here more especially to the latter stages of the operation.

From 6 bushels of malt, properly crushed, 100 gallons of wort may be extracted by due mashing, the first water of infusion being of the temperature of 160° Fahr., and the next two progressively hotter, for exhausting the soluble saccharine matter. When the wort is cooled to 75°, from 3 to 4 gallons of good yeast are stirred into it in the fermenting tun, and when it has been in brisk fermentation for about 40 hours, it is ready for transference into the vessels in which the acetification is to be accomplished.

The transformation of the fermented wort into vinegar was formerly effected in two ways, which were entirely opposite in their manner of operation. In one case the casks containing the fermented malt infusion (or *gyle*) were placed in close rooms, maintained at a uniform temperature, as already described in the preparation of wine vinegar; in the other, they were arranged in rows in an open field, where they remained many months. As regards the convenience and interests of the manufacturer, it appears that each method had its respective advantages, but both are now almost entirely abandoned for the more modern processes to be described: a short notice of the fielding process is, however, retained.

When *fielding* is resorted to, it must be commenced in the spring months, and then left to complete itself during the warm season. The *fielding* method requires a much larger extent of space and utensils than the stoving process. The casks are placed in several parallel tiers, with their bung-side upwards and left open. Beneath some of the paths which separate the rows of casks are pipes communicating with the '*back*' at the top of the brewhouse; and in the centre of each is a valve, opening into a concealed pipe. When the casks are about to be filled, a flexible hose is screwed on to this opening, the other end being inserted into the bung-hole of the cask, and the liquor in the '*gyle back*' at the brewhouse, by its hydrostatic pressure flows through the underlying pipe and hose into the cask. The hose is so long as to admit of reaching all the casks in the same row, and is guided by a workman.

After some months the vinegar is made, and is drawn off by the following operation:—A long trough or sluice is laid by the side of one of the rows of casks, into which the vinegar is transferred by means of a syphon, whose shorter limb is inserted into the bung-hole of the cask. The trough inclines a little from one end to the other, and its lower end rests on a kind of travelling tank or cistern, wherein the vinegar from several casks is collected. A hose descends from the tank to the open valve of the underground pipe, which terminates in one of the buildings or stores, and, by the agency of a steam-boiler and machinery, the pipe is exhausted of its air, and this causes the vinegar to flow through the hose into the valve of the pipe, and thence into the factory buildings. By this arrangement the whole of the vinegar is speedily drawn off. From the storehouse, where the vinegar is received, it is pumped into the *refining* or *rape* vessels.

These rape vessels are generally filled with the stalks and skins of grapes or raisins (the refuse of the British wine manufacture is generally used), and the liquor being admitted at the top, is allowed slowly to filter through them; after passing through, it is pumped up again to the top, and this process is repeated until the acetification is complete. Sometimes wood-shavings, straw, or spent tan, are substituted for the grapes refuse, but the latter is generally preferred.

By this process, not only is the oxidation of the alcohol completed, but coagulable nitrogenous and mucilaginous matter is separated, and thus the vinegar rendered *bright*. It is finally pumped into store vats, where it is kept until put into casks for sale.

3. Sugar, Cider, Fruit, and Beet Vinegars. An excellent vinegar may be made for domestic purposes by adding, to a syrup consisting of one pound and a quarter of sugar for every gallon of water, a quarter of a pint of good yeast. The liquor being maintained at a heat of from 75° to 80° Fahr., acetification will proceed so well that in 2 or 3 days it may be racked off from the sediment into the ripening cask, where it is to be mixed with 1 oz. of cream of tartar and 1 oz. of crushed raisins. When completely freed from the sweet taste, it should be drawn off clear into bottles, and closely corked up. The juices of currants, gooseberries, and many other indigenous fruits, may be acetified either alone or in combination with syrup. Vinegar made by the above process from sugar should have fully the Revenue strength. It will keep much better than malt vinegar, on account of the absence of gluten, and at the present low price of sugar will not cost more, when fined upon beech-chips, than 1*s.* per gallon.

The sugar-solution may likewise be replaced by honey, cider, or any other alcoholic or saccharine liquid. An endless number of prescriptions exist, of which the following example may suffice:—100 parts of water to 13 of brandy, 4 of honey, and 1 of tartar.

Messrs. Neale and Duyck, of London, patented a process, in 1841, for the manufacture of vinegar from *beet-root.*

The saccharine juice is pressed out of the beet, previously rasped to a pulp, then mixed with water and boiled; this solution is fermented with yeast, and finally acetified in the usual way, the process being accelerated by blowing air up through the liquid, which is placed in a cylindrical vessel with fine holes at the bottom.

In some factories large quantities of sour ale and beer are converted into vinegar; but it is usually of an inferior quantity, in consequence of being liable to further fermentation.

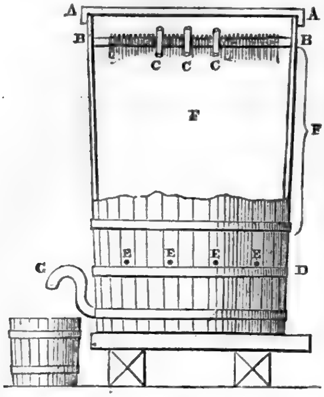
Dr. Stenhouse has shown that when *sea-weed* is subjected to fermentation, at a temperature of 96° Fahr., in the presence of lime, acetate of lime is formed, from which acetic acid may be liberated by the processes described under the head of Pyroligneous Acid. Although such large quantities of sea-weed are found on all our coasts, it does not yet appear that it has hitherto been utilised in this way, although it would still be, to a certain extent, valuable as manure after having been subjected to this process.

4. The German or Quick-Vinegar Process. (*Schnellessigbereitung*, Ger.)—In the manufacture of vinegar it is highly important that as free a supply of air should be admitted to the liquid as possible, since if the oxidation take place but slowly, a considerable loss may be sustained from much of the alcohol, instead of being completely oxidised to acetic acid, being only converted into aldehyde, which, on account of its volatility passes off in the state of vapour. This is secured in the German process by greatly enlarging the surface exposed to the air; which, however, not only diminishes or prevents the formation of aldehyde, but also greatly curtails the time necessary for the whole process. In fact, when this method was first introduced, from the supply of air being insufficient, very great loss was sustained from this cause, which was, however, easily remedied by increasing the number of air-holes in the apparatus.

This *quick-vinegar process* consists in passing the fermented liquor (which generally contains about 50 gallons of brandy of 60 per cent., and 37 gallons of beer or malt-wort, with $\frac{1}{1000}$th of ferment), two or three times through an apparatus called the Vinegar Generator (*Essigbilder*).

This apparatus consists of an oaken tub (*fig.* 2088), narrower at the bottom than at the top, furnished with a loose lid A, with a funnel, through which the liquids for charging the graduator are supplied; below this is a perforated shelf, B, having a number of small holes, loosely filled with packthread, about six inches long, and prevented from falling through by a knot at the upper end. Through this lid there likewise pass some glass tubes, open at both ends, C, which, having their apertures above and below the shelf, act as air-vents. At a distance of about eighteen inches from the bottom is placed another perforated diaphragm, at D; and two inches above this the tub is perforated with eight or ten equidistant holes, E E, an inch to an inch and a half in diameter, which serve to admit atmospheric air. The space F, between the diaphragm and the perforated lid, is filled with shavings of beechwood; by percolating through which, the solution is exposed, over a very considerable surface, to the oxidising influence of the air, which passes in a current upwards through the apparatus. One inch above the bottom is a syphon-shaped discharge pipe G, the upper curvature of which stands one inch below the air-holes in the side of the tub; so that when the liquid in the bottom of the generator, which has passed through the shavings, collects up to this level, it runs off into any vessel placed beneath to receive it.

2088



The analogy between acetification and ordinary processes of decay, and even combustion, is well seen in this process; for, as the oxidation proceeds, the temperature of the liquid rises to 100° or even 104° Fahr.; but if the temperature generated by the process itself be not sufficient, the temperature of the rooms in which the tuns are placed should be artificially raised.

By this methed 150 gallons of vinegar can be manufactured daily in ten tuns, which one man can superintend; and the vinegar, in purity and clearness, resembles distilled vinegar.

It is better to avoid using liquors containing much suspended mucilaginous matter, which, collecting on the chips, quickly chokes up the apparatus, and not only impedes the process, but contaminates the product.

The chips and shavings may with advantage be replaced by charcoal in fragments, which, by the oxygen it contains condensed in its pores, still further accelerates the process. The charcoal would of course require re-igniting from time to time.

Processes for the rapid formation of vinegar have likewise been adopted in this country. So long ago as the year 1824, Mr. Ham obtained a patent for the following method, which is still in operation at several works:—

The apparatus consists of a large vat, in the centre of which is placed a revolving pump, having two or more shoots pierced with holes, so as to cause a constant shower of wash—fermented wort—to descend. The lower part of the vat is charged with wash, the upper part with birch-twigs, piled as high as possible, but without interfering with the revolution of the shoots. Between the surface of the wash and the joist which supports the birch-twigs, a space of three or four inches is unoccupied, and holes are perforated in it, to admit a current of air, either from the atmosphere or from a blowing apparatus.

If the wash be maintained at a temperature of from 90 to 100° Fahr., and the supply of liquid duly proportioned to the mass of the twigs, a charge is generally acetified in about a fortnight. The acetification can of course be arrested at any moment, and the current of air increased or diminished at will.

Generally in England much larger tuns are used than in Germany, the larger mass of matter thus undergoing oxidation generating so much heat that no artificial elevation of temperature is required; and in consequence of the promotion of the process in this way, one of these large tuns, fifteen feet wide at the bottom, fourteen at the top, and thirteen high, turns out as much vinegar as in Germany is obtained from six tubs eighteen feet high and four feet wide.

By the quick process of Ham, when the fermentation is finished, the greatest care ought to be taken that all access of air is excluded from the wash, and that its temperature be reduced to, and maintained at, a heat below the point where acetification commences. Those who, like Messrs. Hill, Evans, and Co., of Worcester, attach great importance to the fabrication of the best-keeping vinegars, are in the habit of filtering the fermented wash, and also of storing it away for many months in a cool situation ere it is passed through the acetifier; and there cannot be a moment's doubt concerning the great value of this practice, not only as regards the appearance and flavour of the resulting vinegar, but also in respect to its dietetic and sanitary properties.

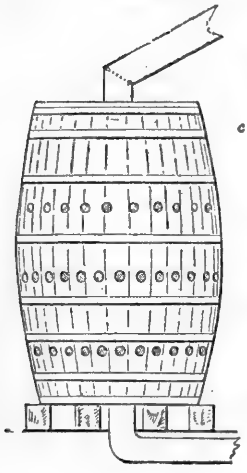
All recently-fermented wash contains a quantity of partially-decomposed gluten, some of which is mechanically suspended merely, but by far the larger portion exists in a state of solution through the agency of carbonic acid gas.

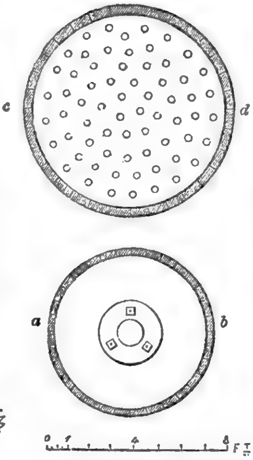
A filter will remove the former, but time alone can dissipate the carbonic acid, and lead to the deposition of the soluble gluten. At all events, time is the only available remedy, for though heat would expel the carbonic acid, yet it would at the same time drive off the alcohol; and agitation in contact with air, though it removed the carbonic acid, would tend to the formation of acetic acid, by which the gluten would be kept in solution more decidedly than before, and thus lead to the production of a turbid, ropy, and impure vinegar, extremely liable to decompose and undergo the putrefactive fermentation. It is obvious, therefore, that the theoretical conditions needed in the treatment of fermented wort by the vinegar-maker are precisely those which we have shown to be in use at Worcester. That is to say, the gluten, when insoluble, should be removed by a filter, and when held in solution by carbonic acid gas, this must be slowly expelled by keeping at a temperature too low for acetification to take place, and which may be assumed at less than 55° Fahr. Fermented wort stored away at this temperature for six months will flow to the acetifier perfectly limpid and bright; it will cause no deposition of gluten upon the birch-twigs, and thus secure complete oxidation; it will rapidly take on the grateful flavour of acetic ether, and never become tainted by the formation of that noxious product aldehyde, which so frequently contaminates ill-made vinegar.

Presuming, however, that all the necessary precautions with respect to care in washing, fermenting, and keeping the wort, have been attended to, we may now pass on to the acetifier, that is to say, Ham's acetifier.

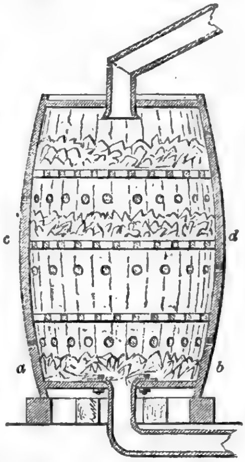
This is a wooden vat or vessel (*figs.* 2089, 2090) about 12 feet in height and from 7 to 8 feet in diameter, closed at top and bottom, except at the opening for the introduction of the wash and the exit of the vinegar. The sides are perforated by a few small holes for the admission of air, and within are three floors or partitions perforated with numerous holes for the passage of the wash through them. Upon these floors are laid bundles of birch-twigs, to favour the dispersion and division of the fluid which passes through the acetifier, and is thus brought into the most immediate contact with the oxygen contained in the vessel, or admitted through the openings in its sides. The fluid or wash is admitted at the top of the acetifier, and suffered to trickle slowly through the masses of birch-twigs and through the partitions, thus causing a rapid absorption of oxygen, and consequent production of vinegar, which with any undecomposed wash flows out at the bottom of the vessel, and is again pumped up to the top, and so on until the process is finished. If we examine the circumstances connected with the formation of vinegar in this way, we shall perceive that it is a case of partial combustion, or, in other words, an example in which an organic compound undergoes oxidation at a temperature and under conditions which prevent the completion of the change.

2089





2090



Every one must have observed that when common coals are thrown upon a fire, a volatile portion immediately bursts into flame, while copious particles of soot or carbon are thrown off unburnt; though of the other constituent of the coal, that is to say, the hydrogen gas, no particle escapes unoxidised. This arises from the fact, that, except at very high temperatures, hydrogen has a greater affinity for oxygen than carbon has; consequently, as the supply of oxygen from atmospheric air in the immediate neighbourhood is limited, the hydrogen seizes upon its equivalent to the exclusion of the carbon, which, therefore, remains, and constitutes soot. Exactly in the same way the hydrogen of the alcohol in the wash oxidises to the exclusion of the carbon, and vinegar is formed from the remaining or carbonaceous element, which becomes itself slightly oxidised.

From this explanation it follows that, as the oxidation of the hydrogen generates heat, there ought to be a very appreciable rise in the temperature during the passage of the wort through the acetifier. And, in practice, this is found to be the case; so that precautions are needed to prevent the heat from rising so high as to vaporise the remaining alcohol of the wash. The temperature sought to be obtained is about 90° to 92° Fahr., at which oxidation goes on freely, and the loss of alcohol is moderate. In using the word 'moderate,' we speak practically rather than chemically: for, in reality, the loss is very serious with strong worts. From practical results, conducted with more than ordinary care, it has been ascertained that about one-third of all the extractive matter of the malt and grain is lost or dissipated during the processes of fermentation and acetification. Thus, a wort having a specific gravity of 1·072, or, in technical language, weighing about 26 lbs. per barrel, affords vinegar containing 5·4 per cent. of pure acetic acid, and a residuary extract of 10 lbs. from 36 gallons. The former of these would indicate 35 lbs. of sugar or 13·7 lbs. per barrel of gravity; whilst the latter shows 3·8 lbs. per barrel; the two united being only 17·5 lbs. instead of 26, the original weight. The loss, therefore, has been 8·5 lbs., or from a specific gravity of 1·072 to less than 1·050. This prodigious destruction of extract seems to imply that great improvements may yet take place in the manufacture of vinegar.

The manufacture of vinegar, by Ham's process, is an extremely interesting operation, and, when conducted with proper care, furnishes results of the most satisfactory and uniform character. These, however, are not to be obtained without a vast amount of experience and the most vigilant attention on the part of the manufacturer. Thus a difference in the water, in the malt, in the mode of washing, in the cooling of the wort, or in the fermentation of the wort, will each give rise to modifications in the acetifying process which no subsequent skill or labour can rectify. There seems no doubt that the most important points in Ham's method are the cooling and fermentation of the wort; though, where perfection is sought for, no one of the other conditions can be omitted or neglected with impunity. We shall, therefore, proceed to treat of these conditions *seriatim*, rather than in the order of their importance. At first sight it might be supposed that the purer the water the better; that is to say, the less the amount of earthy or saline constituents, the more valuable the water would be for making vinegar. Experience, however, teaches us the contrary; and science confirms the truth of this teaching, by pointing out the real nature of the operation. When pure water is made to act at a high temperature upon the ordinary ingredients of a vinegar-maker's mash-tun, it is not alone the sugar, gum, and starch of the grain which enters into solution, for, under such circumstances, the gluten is also dissolved; but this gluten is composed of vegetable albumen and vegetable gelatine, the former of which, as is well known, is capable of being decomposed and precipitated by many earthy and metallic salts, of which the sulphate of lime is one. If, therefore, this salt exists in the water employed for the fabrication of vinegar, or of ale or beer, the wort will contain little or no vegetable albumen; consequently, the vinegar or beer made with such water never becomes cloudy or ropy, as happens when pure water is used, for these defects arise from an excess of albuminous matter. The water used for making the celebrated Burton ale contains a great deal of sulphate of lime; and the spring-water of Worcester, which is employed by the extensive firm of Hill, Evans, and Co., in that city, vinegar-makers, contains also a very large amount of sulphate of lime, and no doubt contributes much towards maintaining the well-established reputation of that firm. Whenever, therefore, much sulphate of lime exists in water, without the presence of any noxious ingredient, such water may always be relied upon as favourable for the production of good beer and vinegar.

As regards the malt, or rather the mixture of malt and grain, employed for the production of wort, the common Scotch distillers' formula is the best, containing, as it always does, a considerable percentage of oats, for the long husk of the oat greatly facilitates the operation of draining, and thus secures the thorough separation of the wort from the spent grains.

In practice it is found necessary to ferment only two gravities, a high and a low, all the other qualities of vinegar being made by mixing or diluting these after acetification. The most common, and unquestionably the best, gravity for fermentation is that which in technical language weighs about 20 lbs., or has a specific gravity of 1·056; the other, or that intended for strong or proof vinegar, being of specific gravity 1·072: this latter affords a vinegar containing about 5½ per cent. of anhydrous acetic acid.

In every instance the fermentation must be carried to its utmost limit, or to zero at least; and in cooling the wort prior to fermentation, great care must be used to prevent the accession of the acetous fermentation before the yeast is added; for if this happens to any considerable extent, the nitrogenised matter of the yeast is then permanently retained in solution by the acetic acid, and this may give rise to the inconvenience called the 'mother.' To secure a perfect vinegar by Ham's process, as much attention is required during the cooling and fermentation as for the finest ale; and this axiom cannot be too strongly inculcated into the minds of vinegar-makers. The heat of the fermenting tun should not exceed 76° Fahr., as the alcohol formed by the process is apt at a higher temperature to pass off in considerable quantity with the carbonic acid, and thus give rise to a loss of vinegar. Presuming that the fermentation has been well conducted, and that the specific gravity of the wash is as low as water, or 1·000, the next step is to pass it through that apparatus which constitutes the great peculiarity of Ham's process. This process is called 'the acetifier.'—*Ure.*

Impurities and Adulterations.

In order to prevent the putrefactive change which often takes place in vinegar, when carelessly prepared by the fermentation of malt-wine, &c., it was at one time supposed to be necessary to add a small quantity of sulphuric acid. This notion has long since been shown to be false; nevertheless, since the addition of 1 part of sulphuric acid to 1,000 of vinegar was permitted by an Excise regulation, and thus the practice has received legal sanction, it is still continued by many manufacturers. So long as the quantity is retained within these limits, and if pure sulphuric acid be used (great care being taken that there is no arsenic present in such oil of vitriol, as is not unfrequently the case in inferior varieties), no danger can ensue from the habit; but occasionally the quantity is much overpassed by dishonest dealers.

Dr. Ure mentions having found by analysis in a sample of vinegar, made by one of the most eminent London manufacturers, with which he supplied the public, no less than 175 grains of the strongest oil of vitriol per gallon, added to vinegar containing only $3\frac{6}{10}$ths per cent. of real acetic acid, giving it an apparent strength after all of only 4 per cent., whereas standard commercial vinegar is rated at 5 per cent.

The method of determining sulphuric acid has already been given, under the head of Acidimetry, and the same remark applies to hydrochloric acid and others.

Hydrochloric acid is rarely intentionally added to vinegar; but it may accidentally be present when the pyroligneous acid has been purified by Völckel's process. It is detected by the precipitate which it gives with solution of nitrate of silver in the presence of nitric acid.

Nitric acid is rarely found in vinegar. For its method of detection, see Nitric Acid.

Wine vinegar generally contains tartaric acid and tartrates; but it is purified from them by distillation.

Sulphurous acid is occasionally met with in pyroligneous acid. This is recognised by its bleaching action on delicate vegetable colours, and by its conversion, under the influence of nitric acid, into sulphuric acid, which is detected by chloride of barium.

Sulphuretted hydrogen is detected by acetate of lead giving a black colouration or precipitate.

Metallic Salts.—If care be not taken in constructing the worm of the still of silver or earthenware, distilled acetic acid is frequently contaminated with small quantities of metal from the still, copper, lead, tin, &c. These metals are detected by the addition of sulphuretted hydrogen, as is fully discussed under the head of the individual metals. Copper is the most commonly found, and it may be detected in very minute quantities by the blue colour which the solution assumes on being supersaturated with ammonia.

It is not uncommon to add to pyroligneous acid, a little colouring-matter and acetic ether, to give it the colour and flavour of wine or malt vinegar; but this can hardly be called an adulteration.

The presence of the products of acetification of cider may be detected by neutralising the vinegar with ammonia, and then adding solution of acetate of lime. Tartrate of lime is, of course, precipitated from the wine vinegar, while the pearly malic acid of the cider affords no precipitate with the lime, but may be detected by acetate of lead, by the pearly scales of malate of lead, hardly soluble in the cold.

For a description of the manufacture of Wood-vinegar, see Acetic Acid and Pyroligneous Acid.

The *Imports* of vinegar were:—

	1870		1873	
	Gals.	Computed real value	Gals.	Valued at
From France . . .	46,146	4,230*l.*	46,168	4,271*l.*
„ other parts . .	7,049	469*l.*	13,394	1,434*l.*

Of the quantity for 1873 54,956 gallons were entered for Home consumption, paying 687*l.* as duty.

The average price fixed for the value has been 1*s.* 10*d.* for the French vinegar, and 1*s.* 4*d.* for the other sorts. Since July 6, 1856, the duty on all vinegar imported has been 3*d.* per gallon.

That the importation of this article varies considerably is shown by the following statement:—

In 1843 we *Imported* 21,784 gallons; in 1845, 195,967 gallons; in 1856, 35,516 gallons; and in 1869, 49,316 gallons.

Of the vinegar made in the United Kingdom, the *Exports* for the three years ending 1870 were as follow:—

				£
1868 . . .	Gallons,	6,903,	computed real value,	647
1869 . .	„	735	„ „	64
1870 . .	„	1,560	„ „	137
1874 . .	„	3,450	„ „	251

VINEGAR, AROMATIC. Strong acetic acid combined with certain aromatics. See Acetic Acid.

VIOLET DYE is produced by a mixture of red and blue colouring-matters which are applied in succession. Silk is dyed a fugitive violet with either archil or brazil wood; but a fine fast violet, first by a crimson with cochineal, without tartar or tin mordant, and, after washing, it is dipped in the indigo-vat. A finish is sometimes given with archil. A violet is also given to silk, by passing it through a solution of verdigris, then through a bath of logwood, and, lastly, through alum-water. A more beautiful violet may be communicated by passing the alumed silk through a bath of brazil wood, and, after washing it in the river, through a bath of archil. Now, all the violets are produced from the aniline series. See Aniline, Murexide, Purple.

VIOLINE. See Aniline Violet.

VIRIDINE. See Carbolic Acid.

VITRIFIABLE COLOURS. See Enamels, Pastes, Pottery, and Stained Glass.

VITRIFIABLE PIGMENTS. The art of painting with vitrifiable pigments has not kept pace with the progress of science, and is far from having attained that degree of perfection of which it is capable. It still presents too many difficulties to prove a fertile field to the artist for his labours; and its products have, for this reason, never held that rank in art which is due to them from the indestructibility and brilliancy of the colours. The reason of this is attributable to the circumstance that the production of good vitrifiable pigments is mere chance work; and, notwithstanding the numerous papers published on the subject, is still the secret of the few. The directions given in larger works and periodicals are very incomplete and indefinite; and even in the otherwise highly valuable *Traité des Arts Céramiques* of Brongniart, the chapter on the preparation of colours is far from satisfactory, and is certainly no frank communication of the experience gathered in the Royal Manufactory of Sèvres.

The branch of painting with vitrifiable pigments which has acquired its greatest development is the art of painting on porcelain. The glaze of hard felspar porcelain, owing to its difficult fusion, produces less alteration upon the tone of a colour of the easily fusible pigments than is the case in painting upon glass, enamel, faïence, &c. The colours for painting upon porcelain are all of them, *after* the firing, coloured lead-glasses throughout; but before this operation, most of them are mere mixtures of colourless lead-glass, the *flux*, and a pigment. In the so-called gold colours, purple, violet and pink, the pigments are preparations of gold, the production of which has hitherto been considered as especially difficult and uncertain. The following are the processes recommended.

Light Purple.—5 grammes of tin turnings are dissolved in boiling nitromuriatic acid, and the solution concentrated in the water-bath until it solidifies on cooling. The perchloride of tin prepared in this manner, and which still contains a slight excess of muriatic acid, is dissolved in a little distilled water, and mixed with 2 grammes of solution of protochloride of tin of 1·700 sp. gr., obtained by boiling tin-turnings in excess with muriatic acid to the required degree of concentration. This mixed solution of tin is poured into a glass vessel, and gradually mixed with 10 itres of distilled water. It must still contain just so much acid that no turbidness results from the separation of oxide of tin; this may be ascertained previously by taking a drop of the concentrated solution of tin upon a glass rod, and mixing it in a watch-glass with distilled water. A clear solution of 0·5 gramme gold in nitromuriatic acid, which must be as neutral as possible, is poured into the solution of tin diluted with 10 litres of water, constantly agitating the whole time. The gold-solution should have been previously evaporated nearly to dryness in the water-bath, then diluted with water, and filtered in the dark.

On adding the gold-solution, the whole liquid acquires a deep red colour, without, however, any precipitate being formed; this instantly separates upon the addition of 50 grammes of solution of ammonia. But if no precipitate should result, which may happen if the amount of ammonia was too great in proportion to the acid contained in the liquid, and in which case the liquid forms a deep red solution, the precipitate immediately results upon the addition of a few drops of concentrated sulphuric acid. It subsides very quickly. The supernatant liquid should be poured off from it as soon as possible, and replaced 5 or 6 times successively by an equal quantity of fresh spring water. When the precipitate has been thus sufficiently washed, it is collected upon a filter: and as soon as the water has drained off completely, removed while still moist with a silver spatula, and mixed intimately upon a ground plate of a glass by means of a spatula and grinder with 20 grammes of lead-glass, previously ground very fine upon the same plate with water. The lead-glass is obtained by fusing together 2 parts of minium with 1 part of quartz-sand and 1 part of calcined borax.

The intimate mixture of gold-purple and lead-glass is slowly dried upon the same glass plate upon which it had been mixed in a moderately warm room, carefully protected from dust, and, when dry, rubbed to a fine powder, and mixed with three grammes of carbonate of silver.

In this manner we obtain 33 grammes of light purple pigments from 0·5 gramme of gold.

The above proportion of lead-glass and carbonate of silver to the gold precipitate holds good only for a certain temperature, at which the colour must be burnt-in upon the porcelain, and which is situated very near the fusing-point of silver.

To obtain the colour with a less degree of heat, the amount of lead-glass added to the gold must be greater, but that of the carbonate of silver less. The same holds good with respect to the preparation of the purple pigment for glass-painting.

The best purple may be spoiled in the baking in the muffle. When this is done at too low a temperature, the colour remains brown and dull; but if the right degree of temperature has been exceeded, it appears pale and bluish. Reducing, and especially acid vapours, vapours of oxide of bismuth, &c., have likewise an injurious effect upon it.

Dark Purple.—The clear and neutral solution of 0·5 gramme gold in nitromuriatic acid is diluted in a glass vessel with 10 litres of distilled water, and mixed under constant agitation with 7·5 grammes of the solution of protochloride of tin of 1·700 sp. gr. prepared in the manner described above. The liquid is coloured of a dark brownish-red; but the precipitate is only deposited on the addition of a few drops of concentrated sulphuric acid. The supernatant liquid is poured off, and replaced five or six times successively with an equal amount of spring water. The precipitate, which is sufficiently washed, is collected on a filter; and after the excess of water is drained off, removed while still moist with a spatula, and mixed, exactly as described for the light purple, upon a glass plate with 10 grammes of the above lead-glass, dried, then reduced to a fine powder, and mixed with 0·5 gramme carbonate of silver; it furnishes about 13 grammes of dark purple pigment. The stated proportion of lead-glass and carbonate of silver to the gold is for the same temperature of firing as given for the mixture of light purple; for a lower temperature, and also for painting upon glass, the quantity of lead-glass must be increased, and that of the silver salt diminished.

Red Violet.—The gold precipitate from 0·5 gramme gold is prepared in the same manner as for the dark purple, and whilst moist taken from the filter, and mixed intimately upon the plate of glass with 12 grammes of a lead-glass prepared by fusing 4 parts of minium with 2 parts of quartz-sand and 1 part calcined borax; it is then dried as above, and reduced to a fine powder upon a plate of glass, but without any addition of silver. The proportion of lead-glass to gold applies likewise for the same degree of temperature as in the case of the light and dark purple pigments; a lower temperature requires a larger proportion of lead-glass. A slight addition of silver to this pigment converts the red violet into a dark purple: and when employed alone for painting upon glass, it gives a very excellent purple.

Blue Violet.—This same gold precipitate of 0·5 gramme gold is mixed, while still moist, upon the glass plate with 10·5 grammes of a lead-glass obtained by fusing 4 parts of minium with 1 of quartz-sand, drying it slowly in the manner above mentioned, and then reducing it to a fine powder upon the glass plate. When the pigment is burnt-in at a lower temperature, a larger addition of lead-glass is required. This blue-violet pigment is more especially adapted for mixing with blue pigments. It is not applicable to glass-painting. The most important requisite in the preparation of good purple and violet vitrifiable pigment is the very minute state of division of the gold in the gold precipitate, and of the latter in the lead-glass, which is accomplished by mixing the moist precipitate with the glass.

By mixing the light purple with the dark purple or with the red-violet, or the red-violet with the dark purple, in different proportions, the artist is able to produce every possible tint of purple and violet. The light purple, without any additional silver, furnishes an amaranth-red colour, like that seen upon the porcelains of the preceding century, when the peculiar property of silver, of converting the amaranth-red into a rose-red colour, does not appear to have been known. Dr. Richter, who at the commencement of this century prepared the pigments for the Royal Berlin manufactory of porcelain, appears, however, to have employed it for his purple, as a very beautiful rose colour may be seen upon the painted porcelain of that time.

Pink.—One gramme of gold is dissolved in nitromuriatic acid; the solution mixed with one of 50 grammes of alum in 20 litres of spring water; then mixed, constantly agitating, with 1·5 gramme solution of protochloride of tin of 1·700 spec. grav., and so much ammonia added until all the alumina is precipitated. When the precipitate has subsided, the supernatant liquid is poured off, and replaced about 10 times successively by an equal amount of fresh spring water; the precipitate is then collected on a filter, and dried at a gentle heat. It weighs about 13·5 grammes; and to prepare the pigment is mixed with 2·5 grammes carbonate of silver, and 70 grammes of the same lead-glass, described under light purple (2 minium, 1 quartz-sand, 1 calcined borax), and reduced to a fine powder on the glass plate.

This colour is adapted only for the production of a light pink ground upon porcelain, and must only be applied in a thin layer; when laid on in a thick layer the gold separates in a metallic state, and no colour is produced.

All the gold colours above described do not furnish, when fused alone in a crucible, red or violet glasses, as might be expected, but dirty brown or yellowish glasses, which appear troubled from the separation of metallic gold and silver; this peculiar beautiful tint is only developed when they are fused upon the porcelain glaze in a layer, which must not be too thick; they then colour it through and through, as a piece of porcelain painted with it shows distinctly in the fracture. If the layer exceeds a certain thickness, the gold and silver separate in a metallic state; and they produce either a liver colour, as for instance the purple and violet pigments, or no colour at all, as is the case with the more fusible pink pigment.

Yellow Pigments for painting upon Porcelain.—The yellow vitrifiable pigments are lead-glasses, coloured either by antimonic acid or oxide of uranium. The antimoniate of potash is prepared by igniting 1 part of finely-powdered metallic antimony with 2 parts of nitre, in a red-hot Hessian crucible, and washing the residue with water. The oxide of uranium is obtained in the fittest state, by heating the nitrate, until the whole of the nitric acid is expelled.

Lemon Yellow.—8 parts of antimoniate of potash, 2½ parts of oxide of zinc, 36 parts of lead-glass (prepared by fusing together 5 parts minium, 2 parts of white sand, and 1 part of calcined borax), are intimately mixed, and heated to redness in a porcelain crucible, which is placed in a Hessian crucible, until the mixture forms a paste; it is then taken out with a spatula, pounded after cooling, and ground upon a plate glass. If the pigment is fused longer than requisite for the perfect union of the ingredients, the yellow colour is converted into a dirty grey by the destruction of the antimoniate of lead.

Light Yellow.—4 parts of antimoniate of potash, 1 part of oxide of zinc, and 36 parts of lead-glass (prepared by fusing together 8 parts of minium and 1 part of white sand), are well mixed, fused in a Hessian crucible, and after cooling, pounded and ground. In the preparation of this colour, long fusion is less injurious than with the preceding one, owing to the absence of the borate of soda in the lead-glass. The colour itself is more intensely yellow than the preceding one, and is extremely well adapted for mixing with red and brown pigments; but it does not furnish such pure tints as that when mixed with green; owing to its higher specific gravity, it flows more freely from the brush, and may be laid on in a thicker layer, without scaling off after the firing.

Dark Yellow, 1.—48 parts minium, 16 parts sand, 8 calcined borax, 16 antimoniate of potash, 4 oxide of zinc, and 5 parts peroxide of iron (*caput mortuum*), are intimately mixed and fused in a Hessian crucible, until the ingredients have perfectly combined, but no longer; otherwise, the golden-yellow colour is converted into a dirty grey, as in the case of the lemon-yellow pigment.

Dark Yellow, 2.—20 parts minium, 2½ white sand, 4¼ antimoniate of potash, 1 part peroxide of iron (*caput mortuum*), and 1 part oxide of zinc, are well mixed and fused in a Hessian crucible. Long fusion is less injurious in this case than in the preceding. Iron-red pigment may be laid on and near this dark yellow 2, without its being destroyed, or the harmony of the tints injuriously affected.

For landscape and figure painting, the above-mentioned yellow pigments should be made less readily fusible, in order to paint with them upon or beneath other colours, without any fear of what has been painted being dissolved by the subjacent or superposed pigment. This property is given to it by the addition of Naples yellow, which is best prepared for this purpose by long-continued ignition of a mixture of 1 part tartar-emetic, 2 parts of nitrate of lead, 4 parts of dry chloride of sodium, in a Hessian crucible, and washing the pounded residue with water. Very useful yellow colours are likewise obtained by mixing this Naples yellow with lead-glass; they are, however, more expensive than those above given. A very excellent yellow for landscape-painting may be prepared, for instance, by mixing 8 parts Naples yellow and 6 parts lead-glass (obtained by fusing 2 parts of minium with 1 of white sand and 1 of calcined borax).

The yellow pigments obtained with antimony, after being burnt-in upon the porcelain, appear under the microscope to be mixtures of a yellow transparent substance (antimoniate of lead?), and a colourless glass, and not homogeneous yellow glasses.

Uranium Yellow.—1 part oxide of uranium, 4 parts lead-glass (prepared by fusing 8 parts minium with 1 part white sand), are intimately mixed and ground upon a glass plate. This colour is not adapted for mixing with others, with which it produces discordant tints. It may be shaded with dark purple or violet.

Uranium Orange.—2 parts oxide of uranium, 1 part chloride of silver, and 3 parts bismuth glass, (prepared by fusing 4 parts of oxide of bismuth with 1 part of crystallised boracic acid), are intimately mixed and ground upon a plate glass. This orange is not adapted, any more than the yellow pigment, for being mixed with other colours. When examined under the microscope, after being burnt-in upon porcelain, the uranium pigments appear as pale yellow-coloured glasses, in which unaltered oxide of uranium is suspended. Only a small portion, therefore, of the oxide of uranium has dissolved in the fusing.

Green Pigments for painting upon Porcelain. Blue Green.—10 parts of the chromate of protoxide of mercury and 1 part of chemically pure oxide of cobalt are ground upon a glass plate, in order to produce as intimate a mixture as possible; the mixture is then heated in a porcelain tube, open at both ends, until the whole of the mercury is expelled. The beautiful blueish-green powder thus obtained is then transferred into a porcelain crucible, and the lid cemented to it with glaze. The full crucible is exposed to the highest temperature of the porcelain furnace during one firing, the crucible carefully broken after the cooling, and the pigment washed with water, to remove a small quantity of chromate of potash. In this manner a compound of oxide of chromium and oxide of cobalt is obtained in nearly equivalent proportions, which possesses the bluish-green colour of verdigris.

The blue-green pigment consists of a mixture of 1 part of the above compound of oxide of chromium and oxide of cobalt, ½ part of oxide of zinc, and 5 parts of lead-glass (prepared by fusing together 2 parts minium, 1 part white sand, and 1 part calcined borax), which are mixed and ground upon the glass plate. By mixing this blue-green with lemon-yellow, any desired intermediate tint may be produced. 1 part of blue-green to 6 parts of lemon-yellow furnishes a beautiful grass-green.

Dark Green.—The chromate of mercury is treated separately in the same way as the mixture of it with oxide of cobalt for the blue-green; and 1 part of the beautiful green oxide of chromium thus obtained is mixed with 3 parts of the same lead-glass as given under blue-green, and ground upon the glass plate.

Green for Shading.—8 parts chromate of mercury and 1 part oxide of cobalt are intimately mixed, and exposed in a shallow dish to the strongest heat of the porcelain furnace, during one of the bakings. In this manner a compound of oxide of chromium and oxide of cobalt is obtained, of a greenish-black colour, which, mixed with twice the weight of the lead-glass directed for the blue-green, furnishes a very infusible blackish-green colour, for shading other green colours.

When thin splinters of the green pigments of chromium, burnt-in upon porcelain, are examined under the microscope, it is distinctly seen that particles of the oxide of chromium, or of the oxide of chromium and cobalt, are suspended, undissolved, in the colourless lead-glass.

Blue Pigments for painting upon Porcelain. Dark Blue.—1 part chemically pure oxide of cobalt, 1 part oxide of zinc, 1 part lead-glass (prepared by fusing together 2 parts of minium and 1 of white sand), are well mixed and fused in a porcelain crucible, for at least 3 hours, at a red heat: then poured out, reduced to powder, and ground upon the glass. When this pigment cools slowly, it solidifies to a mass of acicular crystals. Long-continued fusion, at not too high a temperature, is requisite to obtain a beautiful tint; this is best attained by fusing it, during one of the bakings, in the second floor of the porcelain furnace; this is also the cheapest and best way of fusing the lead-glasses.

Light Blue.—1 part oxide of cobalt, 2 parts oxide of zinc, 6 parts lead-glass (prepared by fusing together 2 parts of minium and 1 of white sand, and 1½ part lead-glass (prepared by fusing together 2 parts of minium, 1 part white sand, and 1 part calcined borax), are well mixed and fused, as directed for the dark blue.

Blue for Shading.—10 parts oxide of cobalt, 9 parts oxide of zinc, 25 parts of lead-glass (obtained by fusing 2 parts of minium and 1 of white sand), and 5 parts of lead-glass (prepared by fusing together 2 parts of minium, 1 part of white sand, and 1 part of calcined borax), are mixed and fused, as directed for the dark blue. The colour is only used for shading, or to be applied upon or beneath the two preceding blue pigments, for which purpose it is admirably suited, from its being very difficult of fusion.

Sky Blue.—2 parts of dark blue, 1 part oxide of zinc, and 4 parts of lead-glass (prepared by fusing 4 parts minium with 1 of white sand), are intimately mixed and ground upon the glass plate. This pigment is employed, either alone, or mixed with other colours, only for painting the sky in landscape.

The blue pigments described likewise appear under the microscope, after having been burnt-in upon the porcelain, not to be homogeneous blue glasses, but mixtures of a transparent blue substance (silicate of cobalt and zinc?) and a colourless glass.

Turquoise Blue.—3 parts of chemically pure oxide of cobalt, and 1 part of pure oxide of zinc, are dissolved together in sulphuric acid; then an aqueous solution of 40 parts ammonia-alum added, the mixed solutions evaporated to dryness, and the residue heated to expel the whole of the water; then reduced to a powder, and exposed in a crucible to an intense red heat for several hours. The colour is most beautiful, when it has been exposed, during one firing, to the heat of the porcelain furnace. It is a combination of nearly 4 equivs. alumina, 3 equivs. oxide of cobalt, and 1 equiv. oxide of zinc, and is of a beautiful turquoise-blue colour. When the oxides are mixed in other proportions than those above given, they do not furnish such beautiful coloured compounds. To impart to it a slightly greenish tint, a little moist recently-precipitated protochromate of mercury is mixed with the above-described solution of ammonia, alum, zinc, and cobalt; with the above quantities, $\frac{1}{10}$th part of the chromate, calculated in the dry state, suffices.

The turquoise-blue vitrifiable pigment is prepared by mixing one part of the compound of alumina-oxide of zinc and cobalt with 2 parts of bismuth glass (prepared by fusing 5 parts of oxide of bismuth with 1 part of crystallised boracic acid).

The receipt for the preparation of the turquoise-blue pigment, communicated in the *Traité des Arts Céramiques* by Brongniart, is incorrect; for a lead-glass of the composition there given (3 parts minium, 1 part sand, 1 part boracic acid) destroys the turquoise-blue pigment entirely on fusion, and only a dirty bluish-grey colour is produced. On examining under the microscope the turquoise-blue pigment burnt-in upon porcelain, it appears to be a mixture of a transparent blue substance and a colourless glass. The transparent blue substance in all probability is the above-described compound of oxide of cobalt and alumina, which is of itself transparent under the microscope, but the transparency of which is increased by the surrounding fused glass of bismuth, just like the fibres of paper by oil. This is probably the case also with the microscopic blue constituent of the other blue vitrifiable pigments, and which is probably silicate of zinc and cobalt; for this, when prepared separately, forms a pure blue transparent powder.

Black and Grey Colours for painting upon Porcelain. Iridium Black.—Iridium, as obtained in commerce from Russia in the state of a fine grey powder, is mixed with an equal weight of calcined chloride of sodium, and heated to a faint red in a porcelain tube, through which a current of chlorine is passed. In this manner a portion of the iridium is converted into the bichloride of iridium and sodium, which is dissolved out with water from the ignited mass. The aqueous solution of the double salt is evaporated to dryness with carbonate of soda, and then extracted with water, which furnishes black sesquioxide of iridium. This is dried and mixed with twice its weight of lead-glass (prepared by fusing together 12 parts of minium, 3 parts of white sand, and 1 part of calcined borax), and ground upon a plate of glass. The iridium, which remained undecomposed in the first treatment with sea-salt and chlorine, is again submitted to the same treatment.

Iridium Grey.—1 part of the sesquioxide of iridium, 4 parts of oxide of zinc, and 22 parts of lead-glass (prepared by fusing together 5 parts of minium, 2 parts of sand, and 1 part of calcined borax) are intimately mixed and ground fine upon a plate of glass. On microscopical examination of the iridium pigments after they have been burnt-in upon porcelain, the sesquioxide of iridium is seen to be suspended in the transparent fused lead-glass. It is owing to the unalterability of the sesquioxide of iridium that it admits of being mixed with all other vitrifiable colours without injuriously affecting the tints, as is the case with all the other vitrifiable grey and black pigments.

Black from Cobalt and Manganese.—2 parts of sulphate of cobalt deprived of its water of crystallisation, 2 parts of dry protosulphate of manganese, and 5 parts of nitre, are intimately mixed, and heated to redness in a Hessian crucible until the whole of the nitre is decomposed. The calcined mass, exhausted with boiling water, furnishes a deep black powder, which consists of a combination of oxide of cobalt and oxide of manganese. 1 part of this compound is mixed with 2½ parts of lead-glass (prepared by fusing together 5 parts of minium, 2 parts of sand, and 1 part calcined borax), and ground fine upon a plate of glass.

Grey from Cobalt and Manganese.—2 parts of the above compound of the oxide of cobalt and manganese, 1 part oxide of zinc, and 9 parts of lead-glass (prepared by fusing together 5 parts of minium, 2 parts of sand, and 1 part of calcined borax) are mixed and ground fine.

These black and grey pigments are far less expensive to prepare than those from iridium, and are not inferior to them in colour; but they do not mix so well with other colours, and when baked several times they vary their tint somewhat, which renders their application less certain. When these colours burnt-in upon porcelain are examined under the microscope, it is seen that the oxide of cobalt and manganese is not dissolved by the lead-glass, but merely suspended in it.

Besides these colours, a very infusible black is used in painting, which is not acted upon by the superposed colours in the fusion; it is the—

Ground Black, which consists of 5 parts of blue violet (gold-purple), 1⅔rds part of oxide of manganese and cobalt, and 1⅔rds part of oxide of zinc; these are intimately mixed and ground fine upon a plate of glass.

White for Covering.—1 part minium, 1 part white sand, and 1 part crystallised boracic acid, are well mixed, and fused in a porcelain crucible. This white enamel has the peculiarity of forming a colourless clear glass when quickly cooled, for instance, when poured into water; while, when slowly cooled, it remains perfectly white and opaque. On heating the clear glass to its melting point, it loses its transparency, and becomes opaque as before. This property it possesses in common with the enamels, the opacity of which is produced by arsenic or tungstic acid; probably the opacity in the present case is produced by the separation of silicate of lead, as in the white enamels by arseniate or tungstate of potash, or by oxide of zinc. It is, however, of excessive minuteness; for under the microscope, even with the highest power, the glass merely exhibits a yellowish turbidness, and no individual particles are visible.

This white serves for marking the lightest part of the pictures, where it is impossible to produce them by exposing the bare surface of the white porcelain; it is also frequently mixed in small quantity with the yellow and green pigments, to make them cover well.

Lead Flux.—A colourless lead-glass for touching-up those parts of the painting which have remained dull, and for mixing with those pigments which are not easy of fusion, is obtained by mixing together 5 parts of minium, 2 parts of white sand, and 1 part of calcined borax.

Red and Brown Vitrifiable Pigments derived from Peroxide of Iron for painting upon Porcelain. Yellow-Red.—Anhydrous sulphate of the peroxide of iron is heated to redness on a dish in an open muffle, and constantly stirred with an iron spatula until the greater portion of the sulphuric acid has been expelled, and a sample mixed with water upon a glass plate exhibits a beautiful yellowish-red colour; after cooling, the peroxide of iron is freed by washing with water from any undecomposed sulphate, and dried. To prepare the pigment, 7 parts of the yellowish-red peroxide of iron are well mixed with 24 parts of lead-glass (prepared by fusing together 12 parts of minium, 3 parts of sand, and 1 part of calcined borax), and ground fine upon a plate of glass.

Brown Red.—When the persulphate of iron is heated to redness until the whole of the sulphuric acid is expelled, and a sample exhibits a dark red colour, the peroxide of iron is well suited for a brownish-red pigment, which is prepared in the same manner as directed for the yellowish-red.

Bluish Red (*Pompadour*).—When the persulphate is heated still more strongly, it is deprived of its loose consistency, becomes heavier, and acquires a bluish-red colour.

To hit this point exactly when the oxide of iron has assumed the desired carmine tint is not so easy, as it changes very rapidly at these temperatures.

The pigment is prepared by mixing 2 parts of the purple-coloured peroxide of iron with 5 parts of lead-glass, obtained by fusing together 5 parts of minium, 2 parts of sand, and 1 part of calcined borax.

Chestnut Brown.—This colour of various shades, even to black, is acquired by the peroxide of iron, at still higher degrees of heat than required for the preparation of red colours; the pigments are prepared by mixing 2 parts of the chestnut-brown peroxide of iron with 5 parts of lead-glass, prepared by fusing together 12 parts of minium, 3 parts of sand, and 1 part of calcined borax.

Chamois.—1 part of the hydrate of the peroxide of iron, prepared by precipitating the peroxide of iron with ammonia is mixed with 4 parts of the lead-glass, described in the preceding, and the mixture ground fine on a plate of glass. This colour is laid on very thin, and serves to produce a yellowish-brown ground.

Flesh Colour.—1 part of peroxide of iron, 4 parts of dark yellow 2, and 10 parts of lead-glass, prepared as described under chestnut-brown, are well mixed and ground fine upon a plate of glass. This colour can also only be employed in a thin layer. Various tints may be given to it by mixing it with a red peroxide of iron, sky-blue, or dark yellow 2. The red of the cheeks and lips are painted upon it with Pompadour-red.

When the above colours are burnt-in upon porcelain, it is distinctly seen under the microscope that the peroxide of iron is suspended unaltered in the clear lead-glass; at least the quantity dissolved by the fused lead-glass is so small that it is not perceptibly coloured.

Various Brown Pigments for painting upon Porcelain. Light Brown, 1.—6 parts of dry protosulphate of iron, 4 parts of dry sulphate of zinc, and 13 parts of nitre are well mixed, and heated to a redness in a Hessian crucible, until the whole of the nitre is decomposed. When cold, the crucible is broken, the residue removed, and separated by boiling with water from soluble matters. A yellowish-brown powder remains, which is a combination of oxide of zinc with peroxide of iron. The pigment is made by mixing 2 parts of this compound with 5 parts of lead-glass, prepared by fusing together 12 parts of minium, 3 parts of sand, and 1 part of calcined borax.

Light Brown, 2.—2 parts of dry sulphate of iron, 2 parts of dry sulphate of zinc, and 5 parts of nitre, are treated in the same manner as described for light brown 1. The resulting compound of oxide of zinc and iron is of a lighter tint; the pigment is prepared from it as above.

Light Brown, 3.—1 part of dry sulphate of iron, 2 parts of dry sulphate of zinc, and 4 parts of nitre are treated as directed for 1 and 2.

The light brown colours, after having been burnt-in upon porcelain, exhibited, under the microscope, the transparent particles of the yellowish oxide of iron and zinc suspended in the colourless lead-glass.

Bistre Brown, 1.—1 part dry sulphate of manganese, 8 parts of dry sulphate of zinc, 12 parts dry sulphate of iron, and 26 parts nitre, are treated as directed for light brown 1, and the resulting dark brown powder (a combination of the oxides of zinc, iron, and manganese), mixed with 2½ times its weight of lead-glass of the same composition as for light brown 1.

Bistre Brown, 2.—1 part dry sulphate of manganese, 4 parts dry sulphate of iron, 4 parts dry sulphate of zinc, 12 parts nitre, are treated as for bistre brown 1. The colour is somewhat darker.

Sepia Brown, 1.—1 part dry sulphate of iron, 1 part dry sulphate of manganese, 2 parts dry sulphate of zinc, and 5 parts nitre, are treated as directed for light brown 1, and the greyish-brown pigment thus obtained mixed with 2½ times its weight of lead-glass of the above composition.

Sepia Brown, 2.—1 part calcined sulphate of iron, 2 parts calcined sulphate of manganese, 6 parts calcined sulphate of zinc, and 10 parts nitre, are treated as for sepia 1.

Dark Brown.—1 part dry sulphate of cobalt, 4 parts dry sulphate of zinc, 4 parts dry sulphate of iron, and 10 parts of nitre, are mixed and treated as directed for light brown 1. The resulting beautiful dark reddish-brown combination of the oxides of cobalt, zinc, and iron is mixed with 2½ times its weight of the same lead-glass as for the preceding colours.

Chrome Brown.—1 part of hydrated peroxide of iron is intimately mixed with 2 parts of the chromate of the protoxide of mercury, and then heated to redness in a dish, in an open muffle, to expel the whole of the mercury. The dark reddish-brown compound of the oxides of chromium and iron is mixed with 3 times its weight of lead-glass, prepared by fusing together 5 parts of minium, 2 parts of sand, and 1 part of calcined borax.

When examined under the microscope, after being burnt-in upon porcelain, these different brown colours also show that the dark compounds are simply suspended in the lead-glass, and not, or merely to a small extent, dissolved. The direction above given for preparing the coloured combinations of the oxides in the dry way, for the bodies which constitute the different brown pigments, is cheaper and more certain than the precipitation of the mixed solutions by carbonate of soda and calcination of the washed precipitate, which also answers. If, however, the several oxides were to be mixed with the lead-glass separately, instead of combined, the colours would not be pure, that is to say they would exhibit after the firing different tints in a thick and thin layer; they would moreover possess a totally different colour before the burning from that which they acquire after that operation, and would thus contribute to deceive the artist.

Gold purple is obtained, according to the process of Ladersdorff, by mixing a solution of 1 part ducat gold, in 4 parts *aqua regia*, with 1 drachm of tin-salt dissolved in 4 oz. distilled water, and a solution of 1 drachm of gum in 3 oz. of water, in the following proportions:—

Distilled water	3 oz.
Solution of gum arabic	28 grs.
„ of tin-salt	14 „
„ of gold	23 „

and adding alcohol of 0·863 spec. grav., until the liquid begins to grows turbid. The purple is deposited and washed with spirit of 0·958. The dried precipitate has a brownish colour, and furnishes, when all the gum has been carefully removed by washing, a very beautiful purple after the firing.

According to Fuchs, 1 oz. *liq. ferri muriat. oxydati*, Ph. bor., is mixed with 3 oz. of distilled water, and a solution of 1 oz. protochloride of tin in 6 oz. distilled water, and 10 drops of muriatic acid added until the whole has acquired a greenish colour, when a further addition of 16 oz. of distilled water is made.

On the other hand, some ducat gold is heated to boiling with pure nitric acid, until all the gold is dissolved. An excess of acid should be avoided. 360 parts of distilled water are added to this solution of gold; and then the above solution of iron and tin gradually poured into it until the whole of the purple is precipitated. This precipitate has likewise a brownish tint after drying, but furnishes a beautiful purple after burning.

It has been found, however, that purple prepared according to the following process is preferable, especially as regards the external appearance. A mixture of 4 parts pure nitric acid of 1·24 spec. grav., and 1 part pure muriatic acid, which is mixed with half as much pure alcohol of 0·863, and chemically pure tin, gradually added in small portions until no more is dissolved; the solution must be effected slowly, on which account the vessel containing the mixture should be placed in snow or cold water. The carefully decanted solution is diluted with 80 times its weight of distilled water, and mixed with a solution of gold, prepared according to the above directions. The precipitate is purple-red, and remains so after drying. The tin-solution for this purpose cannot be preserved long, otherwise nitric ether is formed; and the higher oxidation of the tin-salt no longer furnishes such beautiful precipitates with gold as the recently-prepared solution.

For mixing with the purple in order to produce a rose colour, the author does not employ a carbonate of silver, but the metal in a very minute state of division, obtained by mixing the finest silver-leaf with honey and a few drops of ether, and well grinding it, when the honey is washed out with water. Mr. Waechter uses as a flux for the purple colours a lead-glass, consisting of 6 parts minium, 2 parts silica, and 2 parts calcined borax.

With respect to the chrome colours, he observes, that the expensive method for their preparation by means of the chromate of the protoxide of mercury is still the only one by means of which a fine colour can be obtained.

Cobalt Colours.—In purifying the cobalt for porcelain colours, the removal of the whole of the arsenic is of less consequence than that of the iron. Cobalt ores from various localities, Tunaberg, Saxony, and Thuringia, are treated in the following manner. The mineral is reduced to a fine powder in an iron mortar, kept for the purpose, and mixed with $\frac{1}{5}$th its weight of charcoal-powder; then exposed in Hessian crucibles to a red heat under a chimney with a good draught or in the open air, and roasted as long as arsenical vapours escape, a very disagreeable operation, which lasts several hours. The ore thus prepared is now boiled over the fire with a mixture of 4 parts nitre and 1 part muriatic acid, 1 part of which is diluted with 3 parts of water. This operation is repeated about 3 times, with less acid. The liquids are allowed to settle, the clear portion decanted, the remainder diluted with water and filtered, and the solution evaporated to dryness. The dry mass is mixed with some water, heated, and separated by filtration from the residue of arseniate of iron. The green liquid, which now contains more or less cobalt, iron, nickel, and manganese, is mixed with a filtered solution of pearlash, until the dirty red precipitate begins to turn blue. Care and experience in this operation are requisite, otherwise a loss of cobalt might result. The precipitate of arseniate and carbonate of iron, which at the same time contains nickel and manganese, is separated by filtration, and the beautiful red liquid mixed with more of the solution of pearlash until the whole of the cobalt is precipitated; the precipitate is carefully washed and dried. This hydrated oxide of cobalt is sufficiently pure for technical purposes, and answers just as well as that prepared from oxalate of cobalt or by caustic ammonia.

For painting, the oxide of cobalt is heated in a Hessian crucible with 1 part silica, and 1½ part oxide of zinc for two hours in a blast-furnace, then reduced to a fine powder in a porcelain mortar, and mixed with an equal weight of lead-glass.

Yellow Colour.—A beautiful yellow is obtained from 2 oz. minium, ½ oz. *Stib. oxydat. alb. abl.* 2 drms. oxide of zinc, 2 drms. 2 scruples calcined borax, ½ oz. silica, ½ drm. dry carbonate of soda, and 1 scruple *ferr. oxydat. fuscum,* which are well mixed, fused in a crucible, and then ground fine.—*Waechter.*

VITRIOL, from *Vitrum,* 'glass,' is the old chemical, and still the vulgar appellation of sulphuric acid, and of many of its compounds. which in certain states have a glassy appearance: thus:—*Vitriolic acid,* or oil of vitriol, is sulphuric acid; *blue vitriol,* is sulphate of copper; *green vitriol,* is green sulphate of iron; *vitriol of Mars,* is red sulphate of iron; and *white vitriol,* is sulphate of zinc.

VIVIANITE. A blue iron ore, phosphate of iron. Some fine examples have been found in the mines of Cornwall and Devon. See IRON ORES.

VOLCANIC GLASS. See OBSIDIAN.

VORTEX WATER-WHEEL. See TURBINE.

VRIAC. A name given to kelp by the French makers; *vriac venant,* drift weed; *vriac scié,* cut weed. The same as VAREC.

VULCANITE. Vulcanised india-rubber. See CAOUTCHOUC.

VULPINITE. A siliceous variety of anhydrite, containing 8 per cent. of silica. The vulpinite from Vulpino, near Bergamo in Italy, takes a fine polish, and is used for ornamental purposes. It is known to artists as the *Marmo Bardiglio di Bergamo.*

W

WACKE is an obsolete name for a rock intermediate between clay-slate and basalt. It is generally an earthy decomposing igneous rock.

WAD, or **WADD,** is the provincial name of plumbago in Cumberland; and also of an ore of manganese in Derbyshire and elsewhere, which consists of the peroxide of that metal, associated with nearly its own weight of oxide of iron, &c.

WADDING (*Ouate,* Fr.; *Watte,* Ger.) is the spongy web which serves to line ladies' dresses, &c. *Ouate,* or *Wat,* was the name originally given to the glossy down tufts found in the pods of the plant commonly called *Apocyn,* and by botanists *Asclepias Syriaca,* which was imported from Egypt and Asia Minor for the purpose of stuffing cushions, &c. Wadding is now made with a lap or fleece of cotton prepared by the carding-engine (see *Carding,* COTTON MANUFACTURE), which is applied to tissue-paper by a coat of size, made by boiling the cuttings of hare-skins, and adding a little alum to the gelatinous solution. When two laps are glued with their faces together, they form the most downy kind of wadding.

WAFERS. There are two manners of manufacturing wafers: 1, with wheat-flour and water, for the ordinary kind; and 2, with gelatine. 1. A certain quantity of fine flour is to be diffused through pure water, and so mixed as to leave no glotty particles. This thin pap is then coloured with one or other of the matters to be particularly described under the second head; and which are, vermilion, sulphate of indigo, and gamboge. The pap is not allowed to ferment, but must be employed immediately after it is mixed. Wafers are now but little used, adhesive envelopes having almost superseded them.

The colouring-matters ought not to be of an insalubrious kind.

For red wafers, carmine is well adapted, when they are not to be transparent; but this colour is dear, and can be used only for the finer kinds. Instead of it a decoction of brazil-wood, brightened with a little alum, may be employed.

For yellow, an infusion of saffron or turmeric has been prescribed; but a decoction of weld, fustic, or Persian berries, might be used.

Sulphate of indigo, partially saturated with potash, is used for the blue wafers; and it is mixed with yellow, for the greens. Some recommend the sulphate to be nearly neutralised with chalk, and to treat the liquor with alcohol, in order to obtain the best blue dye for wafers.

Common wafers, are, however, coloured with the substances mentioned at the beginning of this article; and for the cheap kinds, red lead is used instead of vermilion, and turmeric instead of gamboge.

Three new methods of manufacturing wafers were made the subject of a patent by Peter Armand De Comte de Fontainemoreau, in April 1850; the chief feature of which is a layer of metal-foil. In the first of the three forms described, the metal slip or band is to be coated with the ordinary farinaceous paste used for making wafers, for which purpose the slip is laid on one of the jaws of the ordinary iron mould, then a spoonful of paste is poured on it, the mould is shut, and the paste baked as usual. The metal band is lastly punched into wafers, either plain or ornamental.

The second method is to stick these slips to paper with paste, then to dry and punch them out.

By the third plan, strips of gummed paper are fixed to the slips, and a resinous cement is put on the other side. The first two methods require moistening, the third heating. This contrivance is susceptible of much variety of decoration.

WALNUT HUSKS, or **PEELS** (*Brout des noix*, Fr.), are much employed by the French dyers for rooting or giving dun colours.

WALNUT OIL. See OILS.

WANGEES, or *Japan Canes*. A cane imported from China.

WARP (*Chaîne*, Fr.; *Kette*, *Anschweif*, *Zettel*, *Werft*, Ger.) is the name of the longitudinal threads or yarns, whether of cotton, linen, silk, or wool, which being decussated at right angles by the woof or weft threads form a piece of cloth. The warp yarns are parallel, and continuous from end to end of the web. See WEAVING, for a description of the *warping-mill*.

WASH is the fermented wort of the distiller.

WASHING COAL. M. Berard is the inventor of a very successful apparatus for purifying small coal. He exhibited his arrangement at the Great Exhibition of 1851, receiving the Council medal. The decoration of the Legion of Honour and a gold medal was also awarded to him at the Paris Exhibition in 1855. This apparatus, to be presently described, effects, without any manual labour, the following operations:—

1st. The sorting the coal by throwing out the larger pieces.

2nd. Breaking the coal, which is in pieces too large to be subjected to the operation of washing.

3rd. Continuous and perfect purification of the coal.

4th. Loading the purified coal into waggons.

5th. Loading the refuse (pyrites or schist) into waggons for removal.

The power required for the apparatus is that of from four to five horses, and the machine can operate upon from 80 to 100 tons of coal in about twelve hours, if fitted up near the colliery. The expense of the operation of purifying is stated to consist solely in the wages of the workmen charged to conduct the labour of the machine.

The following description of the *figs.* 2091 and 2092, will render the arrangements of M. Berard's machine readily intelligible.

The coal is carried from the mine on a staging, for example, and the tram-waggon, B (*fig.* 2091), is unloaded into a hopper, C, either by opening the bottom or by tilting it (as in the position represented by the dotted lines *b*), by means of a lever. It falls afterwards either on to a table or a moveable grating, D, formed of frames, or of a series of stages, of sloping perforated plates, which immediately sorts it into as many sizes as there are perforated plates.

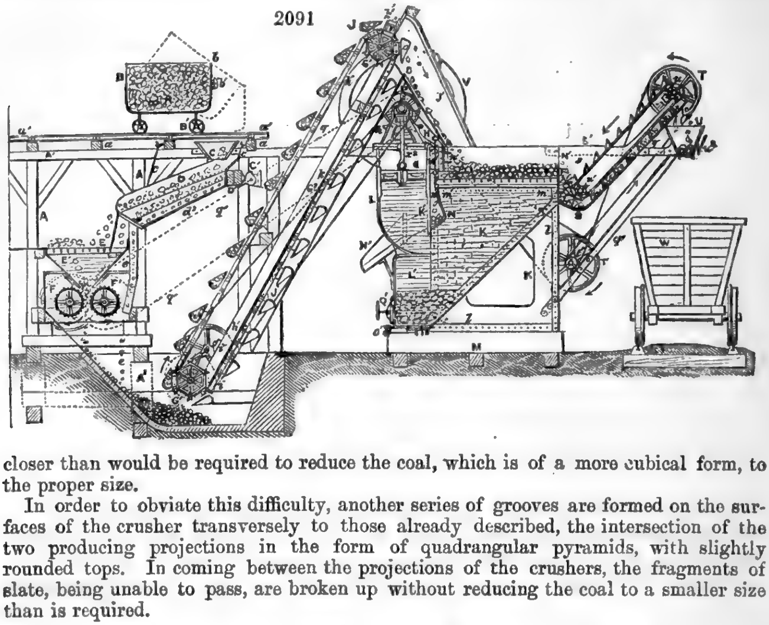
This grating is suspended out of perpendicular by four chains or iron rods, C C, fixed to the framework of the staging A. It is moved by means of a cam motion (an arrangement of a cam and tongue mentonnet), C′, and falls back by its own weight against the stops, which produce concussions or vibrations favourable to the clearing out of the holes and to the descent of the materials. The motion communicated to the grating admits of a much less inclination being given to it than would be the case if it were fixed: the sorting is effected quicker and more perfectly, besides which, the differences of level which it is necessary to preserve are maintained.

The larger pieces rejected by the first plate reach the picking-table E, where a labourer picks out the largest stones and extraneous substances, as fragments of castings, iron, &c.

The fragments which have passed through the upper plate, and are retained by that below, descend direct to the crushers F F′, situated below. Lastly, the fine portions of the coal which have passed through the second perforated plate, fall on to a solid bottom, A′, whence they are thrown, delivered direct into the pit by means of a fixed shoot, *e*.

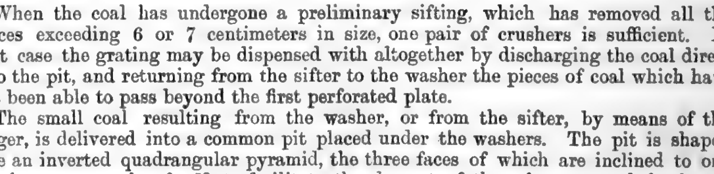
The crushing-cylinders, F F, are made with a covering of cast iron, mounted on an iron shaft. This covering can be easily replaced when worn out. It has on its surface small grooves, which are usually placed longitudinally, parallel with the axis of the cylinder, in order to avoid the slipping of the substances operated on. But it is also necessary to crush fragments of slate which gain admission with the coal, and these consisting of thin, flattened laminæ, it would be necessary to bring the crusher closer than would be required to reduce the coal, which is of a more cubical form, to the proper size.

2091



In order to obviate this difficulty, another series of grooves are formed on the surfaces of the crusher transversely to those already described, the intersection of the two producing projections in the form of quadrangular pyramids, with slightly rounded tops. In coming between the projections of the crushers, the fragments of slate, being unable to pass, are broken up without reducing the coal to a smaller size than is required.

2092



When the coal has undergone a preliminary sifting, which has removed all the pieces exceeding 6 or 7 centimeters in size, one pair of crushers is sufficient. In that case the grating may be dispensed with altogether by discharging the coal direct into the pit, and returning from the sifter to the washer the pieces of coal which have not been able to pass beyond the first perforated plate.

The small coal resulting from the washer, or from the sifter, by means of the jigger, is delivered into a common pit placed under the washers. The pit is shaped like an inverted quadrangular pyramid, the three faces of which are inclined to one another at an angle of 45°, to facilitate the descent of the substance, and the fourth is usually vertical. It is on the latter that an opening is made, which is regulated by a flood-gate.

An elevator, formed of an endless chain, with buckets, raises the coal from the bottom of the pit, and places itself sufficiently high to allow of the final discharge, which may take place into the waggon.

The rate of ascent of the buckets and their capacities are calculated so as to raise 160 to 200 tons of coal in the working hours; but this quantity may be diminished by means of the flood-gate in the pit.

The coal discharged by the elevator falls on the sorter, which ought immediately to divide it, according to size, and distribute it to the ferry-boats.

The classifier is formed of a kind of oblong rectangular chest, made of iron plates, in the inside of which are placed stages of perforated plates, the apertures in which decrease in a downward direction. Sufficient space is allowed between each plate for the motion of the materials. At the bottom of the perforated plates are disposed inclined planes for throwing on one side the product of the sifting, which escapes through a slope made on the side of the sifter. A bottom fixed to the classifier itself, and like it moveable, receives the dust in the finest numbers, if the sifting has been effected in the dry way, or else this bottom is immoveable and fixed to longerons which support the classifier, if the sifting take place in water, as we are about to point out.

The classifier is suspended by two or three pairs of articulated handles turning on axles fixed to longerons: by that means it enjoys an extreme freedom of motion in a longitudinal direction. A rapid reciprocating motion is communicated by a '*bielle*,' which receives the action of a bent axle firmly established on a foundation fixed on the principal wall of the chamber of the machine. The motion of rotation is communicated to the axle by the disposition of an iron pinion *d'angle* working into *a*.

The *bac* is formed of a rectangular chest in cast iron, L′, one part of the bottom of which is inclined at 45°, the other lower parts remaining horizontal.

Opposite one of the lesser sides of the rectangle is placed a cylinder O, opening into the oblong chest at about half its height. The chest L′ is prolonged under the cylinder, in order to increase the stability of the system and the capacity of the drain-well (*puisard*).

A cast-iron box, M M′, is firmly fixed in the interior of the bac, on flanges of cast iron with vertical faces. This box has a slight inclination from M towards M′. It is covered with a perforated plate, usually of copper, fastened to the frame by a number of iron pins or bolts easy of replacement. The size of the holes varies according to that of the matters brought into the bac.

A cast-iron door, N, traverses, opening outward, is fixed at a slight height above the frame, serving as a kind of partition dividing the materials in the bac, and against it a flood-gate N′, by means of which the opening beneath the cast-iron door may be closed at pleasure.

A counter flood-gate, N′, is placed at the lower extremity of the frame; in raising it a barrier is formed of variable height, by means of which the substances between the flood-gate and counter flood-gate may be arrested.

A piston, C, receives from the machine a sufficiently rapid reciprocating motion.

Everything being thus arranged, if the bac is supposed to be filled with water to the level of the front face at N′, and that the substances to be washed fill the space in the bac between this level and the perforated plate of the frame, the piston working upwards and downwards will press the water in the body of the cylinder, and will force it by its incompressibility to pass through the holes in the perforated plate; it will establish above this plate an ascending current, which, if of sufficient power, will raise the substances submerged.

The resistance to the rise of each body will be in proportion to its specific gravity, and the height it will be carried will follow an inverse law, supposing the fragments to be of nearly equal sizes.

The slates which fall over the counter flood-gate fall into a pocket or reservoir, N, whence they are discharged on opening a flood-gate, K′. Pressed by the upper column of water, they slide with a slight admixture of water on the inclined plane, K′ N′, which can be pierced with holes; the water escapes, and the slate only falls directly into the waggon of discharge.

The bent axle of transmission, S S, moves in a groove turning on a pivot at its extremity. The rotation of the axle communicates an oscillating motion to it.

The deposit formed in the drain-well is emptied through an opening of the flood-gate placed at the lower part. An opening serving as a man-hole is reserved for effecting internal repairs without the necessity of raising the frame.

All coal contains a portion of earthy matters or impurities which, in the form of bands or scales, are generally in some degree apparent to the eye, and constitute the ashes and clinker left by combustion. The small coal which is sent out of mines necessarily contains a still larger proportion, frequently exceeding 10 per cent., consisting chiefly of shale and iron pyrites derived from the roof or floor of the seam of coal, or from the bands of impurities interstratified with it. Generally these impurities are so incorporated with the mass of the coal that it must be crushed in order sufficiently to detach them. The pyrites, which contain nearly the whole of the sulphur found in coal-seams, is well known to be very injurious either in a heating or smelting furnace, in the manufacture or working of iron, in gas-making, in coking, and other processes.

Many seams of coal already sunk to, or portions of seams in work, are left underground as unsaleable in consequence of the impurities they contain. Small coal sells at a low price chiefly in consequence of its impurities and the defective coking property which they occasion. It has been estimated that an amount not far short of the quantity of coal sold is sacrificed in producing a commercial article of adequate quality and description. The enormous consumption of coal in this country, amounting to 127 millions of tons per annum, renders the utilisation of a larger portion of the more valuable seams now in course of being exhausted, and the bringing into the market of other seams, objects of national importance.

The differences between the specific gravities of coal and its impurities, allow of their being separated by the action of water when sufficiently crushed. The water process hitherto most commonly adopted is that known as 'jigging,' which consists in forcing the water alternately up and down through the mass of coal. The downward current of water in 'jigging' is prejudicial, and entails a large sacrifice of the finer particles of the best coal; whilst the upward current, from its rapidity and irregularity, is costly both in time and power, besides failing to effect the more perfect separation which is obtained by a slow, continuously ascending or pulsating current, regulated to the proportion of shale in the coal, and to the size of the particles to be acted upon.

Several coal-washing machines have been from time to time introduced, but the machine described sufficiently represents their general character.

Machines have been established in Scotland, Cumberland, Derbyshire, Gloucestershire, and Wales, to purify from 20 to 100 tons of coal per day, at a cost not exceeding 3*d*. per ton, and with a loss not exceeding 2 per cent. of coal.

WATER. (*Eau*, Fr.; *Wasser*, Ger.) There is no substance so extensively used in the operations of nature on our globe, as well as in the workshops of men, as water. To speak of its numerous relationships, even briefly, would demand too much space, and it will be needful to confine ourselves strictly to a consideration of its physical conditions.

A few analyses of river water will convey some idea of the composition of the solid matter held in solution, given in grains per gallon of this fluid:—

	The Thames, Battersea	The Exe, near Exeter	The Dee, near Aberdeen	The Rhine, Basle	The Danube, Vienna	The Elbe, Hamburg	The Seine, Paris
Carbonate of lime	15·10	1·28	1·22	12·79	8·37	6·98	11·3
,, magnesia	1·84	0·09	...	1·35	1·50	0·39	0·4
Silica	1·09	trace	0·20	0·21	0·49	0·54	0·5
Peroxide of iron	0·49	...	...	trace	0·20	0·12	...
,, manganese	...	...	...	...	...		
Alumina	...	...	...	trace	...	...	...
Sulphate of lime	4·26	4·34	0·17	1·54	0·29	0·72	3·6
,, magnesia	...	0·23	0·46	0·39	1·57		0·6
,, soda	1·91	...	...	0·18	0·20	...	...
,, potash	...	0·11	...	...			
Chloride of sodium	2·84	6·05	0·96	0·15	traces	3·94	1·10
,, potassium	...	trace					
,, calcium	...	...	...	...	...		
,, magnesium	...	0·91	...	...	...	...	0·8
Phosphate of lime and iron	...	...	0·11	...	...	...	...
Nitrates	0·50	0·23	...	...	...	...	trace
Organic matter	2·20	2·30	2·60	0·33	...	...	trace

Rain is the probable source of all water. It is almost absolutely pure water if it falls through uncontaminated air. Water is almost colourless, brilliant, without taste or smell, and very transparent. When seen through great depths it has a slightly blue shade of colour. It weighs 252·45 grains per cubic inch at 60° Fahr. in the air. The specific gravity of all substances liquid and solid are taken by their relation to water, which is called 1·000 or 1. Its boiling point at 29·92 bar. pressure is 212° Fahr.; it freezes at 32°, and it evaporates at all temperatures. Its boiling point at 760 meters pressure is called 100° Cent.; freezing point 0°. It assumes, therefore, the gaseous, liquid, and solid states with great facility. The specific heat of water at 32°

Fahr. is taken as 1000. Water is taken to measure amounts of heat also. The heat required to raise 1 gramme of water 1° Cent. is a unit of heat. The amount of heat required to raise 1 lb. of water, one degree of Fahr., requires for its evolution the expenditure of a mechanical force equal to the fall of 772 lbs. through the space of 1 foot. Or 1 gramme of water is heated 1° (Cent.) by an amount of heat represented by the fall of 423·55 grammes through the space of 1 meter. The latent heat of water and the amount required to convert ice at the freezing point into water is 144°, or 144·6° Fahr. (80°–80·34° Cent.) The refractive power of water, or its index of refraction of light, is 1·336; that is, the sine of the angle of incidence is to the sine of the angle of refraction as 1·336 to 1. Refractive power increases below 39·, although density diminishes. Water expands when heated or cooled beyond 39° Fahr., or 3·°9 Centigrade: Playfair and Joule give 39·1; Fraukenhein, 38·85; Plücker and Gessler, 38·8. Hope, who discovered the property, gave 39·5. Water freezes in crystals; one form is not unlike Iceland spar, a rhomboïd. Hail crystallises in six-sided pyramids, base to base; snow frequently with various stellar radiations.

Specific gravity of the vapour of water is 0·622; it is nine times heavier than hydrogen. Water itself is 812 times heavier than the atmospheric air. Water expands by heat, between 32° and 212°, 1 in 21·3 volumes. It expands in cooling below 32°, even if it be not allowed to crystallise. The expansion may be prevented by using smooth vessels and preventing disturbance. It may be cooled in this way to about 7° Fahr. A slight agitation, or the presence of a rough substance, rapidly causes it to shoot out crystals in all directions. The spec. gr. of ice is 0·916, it therefore floats on water. It expands with irresistible force, bursting asunder iron vessels, however strong, in which it may be confined, water-pipes of whatever substance, porous stones which may have absorbed it, and vegetable-cells in which it may be enclosed.

Water heated to 212° Fahr. boils. Long before this period, and even in heating it only a few degrees, it gives off bubbles, which are those of air, from which it is never found free in nature. At 212° the bubbles of vapour are formed and rise to the surface. These bubbles form more readily on certain surfaces; on metals easily, especially if they are not polished. Gay-Lussac gave the difference of the boiling point in metal and glass as two degrees. M. Marcet found it raised to 221° when a glass flask had its inner surface coated with a thin film of shell-lac. When water has ceased to boil in a glass or porcelain vessel, it will begin again instantly if a metallic wire is introduced. Rough glass and porcelain vessels allow water to boil better than smooth. The boiling of water depends on the pressure of the air as well as temperature, as the following shows:—

Barometer, inches	Water boils at degs. Fahr.
27·74	208°
28·29	209°
28·84	210°
29·41	211°
29·92	212°
30·6	213°

This change of boiling point is used to ascertain the height of mountains, 550 feet making a difference of 1 degree. In a vacuum water will boil at 67°. In a Papin's digester it is raised to 300 or 400 without boiling.

WATER-GLASS. See Glass, Water.

WATERING OF STUFFS (*Moirage*, Fr.) is a process to which silk and other textile fabrics are subjected, for causing them to exhibit a variety of undulated reflections and plays of light. See Moire.

WATER-METER. An apparatus by which the quantity of water supplied to a manufactory or to a house can be satisfactorily measured. As a description of gas-meters has been given, it appears requisite that some notice should be taken of an equally important instrument for measuring water. These may be, and are, variously constructed. The principle upon which they are made is in all cases that which we see in action in a water-wheel, a given quantity of water in flowing performs a given quantity of work.

Siemens and Adamson's water-meter is shown in the following figures:—

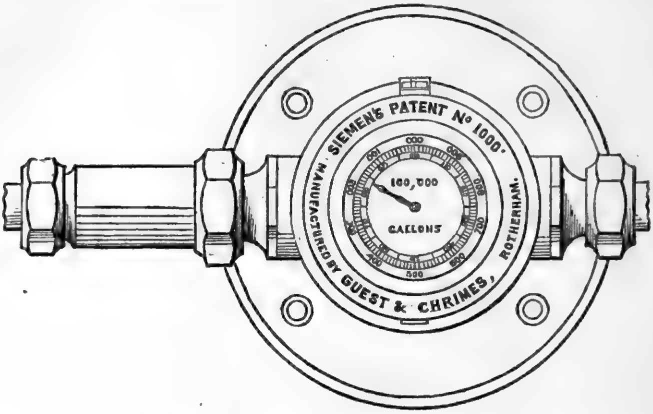
Fig. 2093 is a plan of a meter, looking on the dial and dial-cap.

Fig. 2094 is a section of meter, filter, and unions, complete.

Fig. 2095 is a perspective view of drum or measuring medium, showing the adjusting or regulating vanes *a a a*, and water-ways *b b b*; letters of reference refer to similar parts in all the drawings.

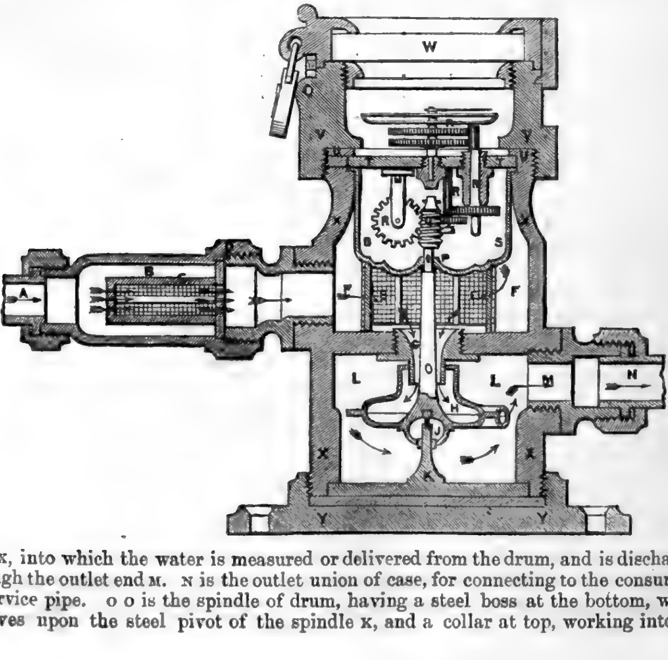
In *fig.* 2094, A is the inlet union of meter for connecting to the Water Company's supply pipe. B is the filter-case. C is a filter, which is for the purpose of preventing foreign and injurious substances passing into the drum of meter. D is a filter-case screw, which connects it with the meter, and is for the purpose of attaching to and detaching from the meter-case, to cleanse the filter C when required. E E is an inner filter, for the purpose of preventing any foreign and injurious matter which might pass the first filter, C (whether from being broken or from any other cause) from entering into the drum.

2093



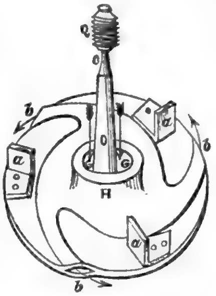
F is an inlet chamber of the meter-case X, into which the water enters, and is conducted into the measuring drum H by means of the conducting tube G. G is the inlet or conducting tube into drum. H is the drum or measuring medium of meter, which is regulated so as to give uniformity of measurement by the adjusting vanes *a a*. J is an oil-cup attached to bottom of drum, which encloses and lubricates the bottom of spindle K. At the upper end of the oil-cup there is a steel boss, which the drum revolves upon. K is the bottom spindle, which has a steel pivot, on which the drum revolves, and is enclosed by the oil-cup or chamber J. L L is the outlet chamber of the meter-case X, into which the water is measured or delivered from the drum, and is discharged through the outlet end M. N is the outlet union of case, for connecting to the consumer's or service pipe. O O is the spindle of drum, having a steel boss at the bottom, which revolves upon the steel pivot of the spindle K, and a collar at top, working into the

2094



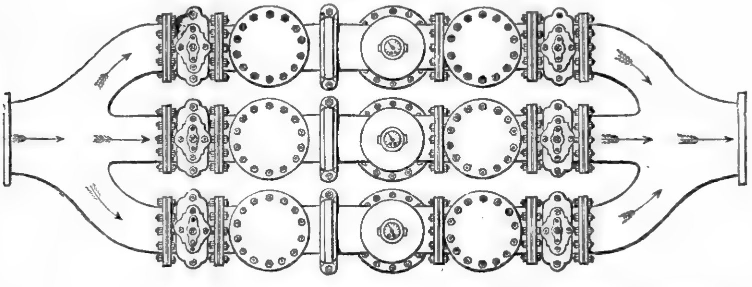
German silver bush P. Q is a screw attached to the top of the drum spindle, for the purpose of giving motion to the wheels of dial-work, and so indicating on a graduated dial the number of feet or gallons of water passed through the meter. R is the dial work. S S is an oil chamber, which is for the purpose of lubricating and protecting the wheels of the dial-work from the action of the water, and so preventing any foreign substance getting upon and injuring them. T is the dial-plate, used for the purpose of making, along with the india-rubber washer U, a sealed or water-tight joint between the oil chamber, where the bottom wheels work, and the upper portion or chamber, where the top or differential wheels and dial work. V is a dial-cap, screwed on to the top of meter-case. W is a glass plate, covering dial. X is an outside metal-case, in which the drum revolves. Y is a bottom plate, for putting in and taking out the drum.

2095

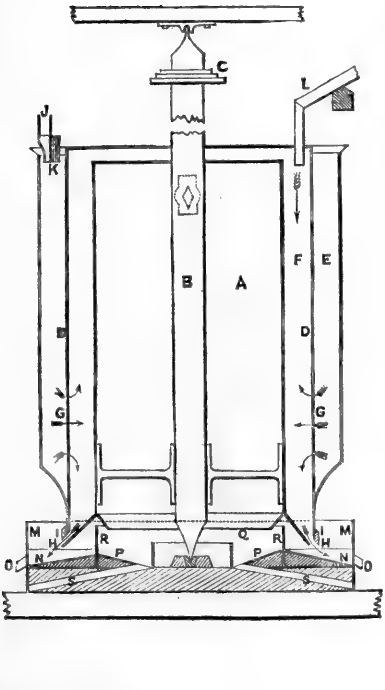


The annexed drawing, *fig.* 2096, shows the arrangement of the meters to measure large quantities of water in connection with town supply or district mains. The plan shown admits of the regular and periodical examination and repairs, when necessary, without interfering with the constant supply. A dirt box is attached to each end of the meters, so as to protect them from injury arising from anything (such as sticks, stones, shells, &c.) which might be in the pipes, and which if allowed to pass might, without this precaution, destroy the accuracy of the measurement, and damage the meter. The sluice valve at each end provides for the periodical examination of the meter and cleaning the dirt box, and when

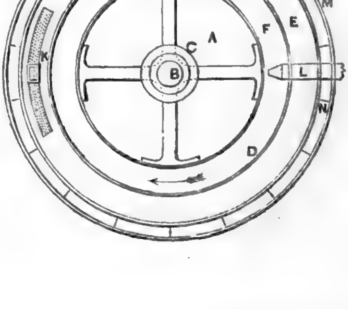
2096



2097



2098



necessary (for the purpose of repairs) the taking-out of the meter. As it is arranged that any two of the meters are of sufficient capacity to deliver the quantity required, it will be apparent that this can be done while the regular supply is going on.

Messrs. Walker and Son's duplex water-meter, *figs.* 2097 and 2098, is somewhat different from this. The water passes into an annular chamber A, in which is a rotator arbor, on which are fixed two measuring screws C, with their blades at contrary angles, and on the same arbor, between these screws, are two cones, which serve to guide the water smoothly on to the screw-blades, and likewise to lift the rotator off its lower pivot and keep it suspended in its bearings whilst in action, thereby preventing end-pressure. The water, by means of a partition, is divided as it enters, and it passes over the screws at opposite sides in two streams of equal force. In the central compartment the water is again divided into two streams, the one descending and passing between the blades of the lower screw, and the other ascending and passing between the blades of the upper screw; these two currents join, and the water passes off by the outlet.

The first example given in some respects resembles a Barker's Mill; while in the other the revolutions of the screws are made to measure the quantity of water passing through the meter.

WATERS, MINERAL. Those waters which contain such a proportion of foreign matter as render them totally unfit for ordinary purposes, and give them a sensible flavour, and a specific action upon the animal economy, are called *mineral* waters. They are various in their composition, temperature, and in their effect upon the system. In regard to temperature they are divided into *warm*, *thermal*, and *cold*. They are generally so far impregnated with acid or saline bodies as to derive from them their peculiarities, and are commonly divided into four classes. *Acidulous* or *carbonated* waters are characterised by an acid taste, and by the disengagement of gas. They contain five or six times their volume of carbonic acid gas; their salts are muriates and carbonates of lime and magnesia, carbonate or sulphate of iron, &c. *Saline* waters contain, in general, salts of soda and lime, or of magnesia and lime, with carbonic acid and oxide of iron. *Chalybeate* or *ferruginous* waters have a decided styptic taste; the iron is sometimes in the state of an oxide, held in solution by carbonic acid, sometimes exists as a sulphate, and sometimes both as a sulphate and carbonate. *Sulphureous* waters are easily recognised by their disagreeable smell, and their property of tarnishing silver and copper.

Dr. Gairdner, in his 'Natural History of Mineral and Thermal Springs,' has endeavoured to generalise the connection between the composition of mineral waters and the rock-formations from which they flow:—1. 'The salts held in solution in mineral waters have no connection with the acid, saline, or earthy matter which enter into the composition of the rocks which they traverse in their passage to the surface of the earth. 2. The mineral waters of the primitive formations are almost all thermal, and generally possess a very high temperature. Their predominant impregnation is sulphuretted hydrogen gas, free carbonic acid gas, carbonate of soda, and, in general, salts with a base of soda, silica, few calcareous salts, except carbonate of lime in some peculiar situations, and but a small quantity of iron. 3. The waters of the palæozoic and older secondary formations participate in those belonging to the primitive rocks. They are generally of a lower temperature, though some of them are still very hot; free carbonic acid is much less common, and sulphuretted hydrogen is almost entirely absent. Salts of soda still predominate, but carbonate is not so common; sulphate of lime is found in the greater number of these waters; silica exists in but two or three examples. 4. The waters of the newer secondary and tertiary formations are as distinctly characterised as those of the primitive rocks, placed at the other extremity of the series. They are all cold. Free carbonic acid is almost entirely absent. Their predominant ingredients are the carbonate and sulphate of lime, sulphate of magnesia, and oxide of iron. 5. The trachytic and basaltic formations, and modern volcanic rocks, present in their mineral waters many of the circumstances of temperature and composition which are found in the waters of granite and other primitive rocks. Sulphuretted hydrogen, carbonic acid, carbonate of soda, carbonate of lime, and silica reappear, and many contain the free sulphuric and hydrochloric acids. The sulphate of lime, magnesian salts, and oxide of iron, are again wanting. 6. It is often found that the mineral waters of a district have almost the same composition, in which case they generally issue from the crystalline and independent formations. In other cases they are subject to great varieties within a comparatively limited space, so that waters of a totally different composition rise close to each other when they emerge from sedimentary rocks.

Sir Charles Lyell, in his Address at the meeting of the British Association at Bath, stated that, 'Notwithstanding the general persistency in character of mineral waters and hot springs ever since they were first known to us, we find on enquiry that some few of them even in historical times have been subject to great changes. These have happened during earthquakes which have been violent enough to disturb the subterranean drainage and alter the shape of the fissures up which the waters ascend. Thus, during the great earthquake at Lisbon, in 1755, the temperature of the spring called La Source de la Reine at Bagnères-de-Suchon, in the Pyrenees, was suddenly raised as much as 75° Fahr., or changed from a cold spring to one of 122° Fahr., a heat which it has since retained. It is also recorded that the hot springs at Bagnères-de-Bigorre, in the same mountain-chain, became suddenly cold during a great earthquake which in 1660 threw down several houses in that town. It has been ascertained that the hot springs of the Pyrenees, the Alps, and many other regions, are situated in lines along with the rocks have been rent, and usually where they have been displaced or faulted.' . . . .

In the regions where volcanic eruptions still occasionally occur, hot-water springs are found in great abundance; sometimes the water of these springs attains a boiling temperature, and some emit steam considerably above boiling point. These springs are most conspicuous in districts where, as in Central France, and the Eifel in Germany, there are indications that the internal fires have comparatively recently become dormant.

At Carlsbad, in Bohemia, there are some very important mineral springs: one of these is a very copious stream, gushing forth with great vehemence. Its temperature is 165° Fahr. The analysis of Berzelius shows the water of this spring to contain:—

Sulphate of soda	2·58714
Carbonate of soda	1·25200
Chloride of sodium	1·04893
Carbonate of lime	0·31219
Fluoride of calcium	0·00331
Phosphate of lime	0·00019
Carbonate of strontia	0·00097
„ of magnesia	0·18221
Phosphate of alumina	0·00034
Carbonate of manganese	a trace
Silex	0·07504
Total	5·46232

Berzelius found that the substances dissolved by carbonic acid in this spring crystallise out, when the carbonic acid escapes, independently of the diminution of the liquid, but that the magnesia and silicic acid were not deposited until the evaporation had taken place.

There are many celebrated mineral springs in England; amongst the most important may be enumerated those of Buxton, Harrowgate, Cheltenham, Leamington, Tunbridge, Epsom, and Bath.

Sir Charles Lyell stated (in the same Address before alluded to) that:—'The thermal waters of Bath are far from being conspicuous among European hot springs for the quantity of mineral matter contained in them in proportion to the water which acts as a solvent.' 'Dr. Daubeny, after devoting a month to the analysis of the Bath waters in 1833, ascertained that the daily evolution of nitrogen gas amounted to no less than 250 cubic feet in volume. This gas, he remarks, is not only characteristic of hot springs, but is largely disengaged from volcanic craters during eruptions. Carbonic acid is another of the gaseous substances discharged by the Bath waters.'

The temperature of the Bath waters varies in different springs from 117° to 120° Fahr. Prof. Roscoe analysed the Bath waters, more particularly the water of the King's Bath spring: he found it contained strontium, lithium, sulphate of calcium, magnesium, and a small quantity of copper.

Dr. Muspratt, in a letter addressed to the Editor of the Chemical News, said:—

'The thermal springs of Buxton issue from fissures in the calcareous rocks, and are attended by often-repeated but suspended volumes of gas, which escape partly as large bubbles, and partly in countless minute vesicles of water, giving to the liquid freshly collected in glass vessels all the appearance of aërated water. As it gurgles up, the water is clear, sparkling, and almost tasteless. The temperature is a little above 32° Fahr., and the specific gravity 1·000339. The most remarkable feature of the Buxton water is the very large quantity of nitrogen which it eviscerates.'

	Cubic inches per gallon.
Nitrogen	204·00
Free Carbonic acid	8·50

The analysis made by Dr. Muspratt of the Buxton water is as follows:—

Carbonate of lime, $CaOCO^2$	8·541
Carbonate of magnesia, $MgOCO^2$	3·741
Carbonate of iron, $FeOCO^2$	0·082
Chloride of calcium, CaCl	1·227
Chloride of magnesium, MgCl	0·463
Chloride of sodium, NaCl	2·404
Chloride of potassium, KCl	0·260
Sulphate of lime, $CaOSO^3$	0·330
Silicic acid, SiO^2	1·044
Organic matter	0·341
Phosphate of lime and alumina, fluoride of calcium, nitric acid, &c.	1·076
	19·510

The celebrated Geysers of Iceland are the hottest known springs in the world. From experiments made by Prof. Bunsen, we learn that at the depth of only 74 feet, at the bottom of the tube a column of water may be in a state of rest, and yet possess a heat of 120° Cent. or 248 Fahr. What then will be the temperature of such water at the depth of a few thousand feet? The Geyser water contains in 10,000 parts:—

	Forchhammer.	Pfaff.
Silicic acid	4·09	8·00
Soda	1·32	—
Chloride of sodium	1·68	1·68
Sulphate of soda (and magnesia)	0·62	1·32
Sulphate of lime	0·34	—
	7·96	11·00

By cooling alone about one-tenth of the silicic acid separates; for the water which Forchhammer received in sealed flasks became cloudy, and left that quantity of silica.

WATER-PRESSURE MACHINERY FOR MINES. See HYDRAULIC MACHINERY.

WATER-PROOF CLOTH. See CAOUTCHOUC.

WATER, PURIFICATION OF. This subject has been already dealt with to some extent while on the subject of filters, and when speaking of the influence of animal-charcoal. Spencer, the discoverer of the electrotype process, appears to have made a discovery proving that magnetic oxide of iron and the protocarbide possess the property of purifying water.

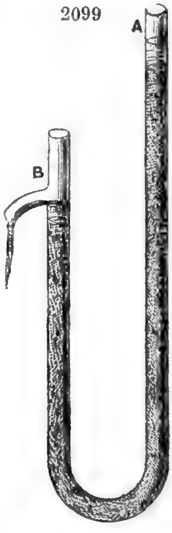
After trying a number of experiments with various descriptions of rocks and minerals, Mr. Spencer found that those containing protoxide of iron (even where it was chemically combined with other substances) effected the filtration of water from even suspended impurity better than any others. Acting on the idea thus suggested, he found that the same oxide, when isolated in the state of 'magnetic oxide,' not only freed water from turbidity more effectually than an equal thickness of sand, but effected its decolouration with marvellous rapidity. On the other hand, the earthy substances entering into the composition of the same rocks, such as silica and alumina, when isolated, were, in the latter respect, perfectly *inert*. From this it was evident that the protoxide of iron, as magnetic oxide—a substance which enters into the composition of so many rocks—was one of nature's chief agents of purification. A most striking experiment was made with some bog-water, darker in colour than ordinary porter, which had been procured from the soakings of an Aberdeenshire peat-bed. *When brought into contact with the magnetic oxide, it was deprived of its colour almost instantaneously, and carbonic acid substituted in its place.*

Perhaps the most extraordinary circumstance is that *the magnetic filtering medium itself suffers no deterioration after any period of operation.* Of course, if its surface becomes fouled with slimy impurity, it requires washing. Its province is confined to forcing the oxygen, always present in the water, into combination with the impure organic matter, and thus *converting it into carbonic acid,* which gas conferred freshness and salubrity on all waters in which it was found. In these results the occult action of catalysis was, for the first time in the history of science, brought at will into artificial every-day operation.

The magnetic oxide was not to be understood as ordinary oxide (rust) of iron. It was, on the contrary, a black crystalline body, hard but brittle, and analogous, in perhaps all respects, to the body formerly termed 'loadstone.' Below redness it never oxidised. Though not plentiful as a natural body, Mr. Spencer had succeeded in forming it artificially, from several iron ores, at a very reasonable rate. Though the magnetic oxide he had obtained from the white carbonate of iron was very effective, yet it had a tendency to be reduced to fine powder by attrition. He became apprehensive, therefore, that this circumstance might ultimately interfere with the rapidity of his filtering operations. This led him to seek some mode of procuring an equally effective though less friable body. After various experiments, he succeeded beyond his anticipations. By very simple means, he had obtained a magnetic body combined with carbon from the hitherto refractory Cumberland hæmatite. This new compound body, which is thus added to metallurgical chemistry, consists of iron, oxygen, and carbon—an equivalent of each; its atomic number is therefore 42. It is very hard, and when polished, has a black metallic lustre. It is highly magnetic, and was said to be as incorrodible as gold or platinum. Its purifying powers were stated to be very great. It can be manufactured cheaply. Mr. Spencer named it protocarbide of iron. He stated that it was not always necessary in practice to have an equivalent of carbon combined with the oxide, as a smaller proportion conferred the requisite hardness, in which case it was prepared more quickly; but, in making, if kept at a low red heat along with uncombined carbon for a longer time, the combination took place in equivalent proportions.

WATER, SEA—*rendered fresh.* The analyses of sea water which have been made at various times, and the results of which will be found elsewhere, prove that that liquid contains from 3½ to 4 per cent. of saline substances, two-thirds at least of which are common salt, and also a certain quantity of organic matters, all of which substances impart to it its well-known taste and odour, and render it unfit for drinking or other domestic purposes.

2099



To render sea water drinkable, and thus avoid the accidents resulting from an insufficient supply, or from an absolute want of fresh water, in sea-voyages, is a problem which may be said to have engaged the attention of men from the very moment they ventured to lose sight of the friendly shore and became navigators; gradually, as the enlargement of commercial operations extended the length of sea-voyages, the difficulty of preserving in a pure state the fresh water taken in store, the necessity of putting up at stations for procuring a fresh supply of it when it is exhausted, the great gain to be realised by being enabled to devote to the stowage of cargo the valuable space occupied by water-tanks and water-casks, have induced many people at various times, and for many years past, to contrive apparatus by means of which sea water would be rendered fit to drink, or by means of which good fresh water could be obtained therefrom.

Fresh water can be obtained from sea water in two ways: the one by distillation, the other by passing it through a layer or column of sand, or of earth, of sufficient thickness or length. In effect, if sea water be poured at A (*fig.* 2099), into a pipe 15 feet high, and full of clean dry sand, the water, which will at first flow at B, will be found pretty fresh and drinkable, but as the operation is continued, the water which flows at B soon becomes brackish; the brackishness gradually augmenting, until, in a very short time, the water which flows at B is actually more salted than that poured at A; because the latter dissolves the salt which had been first retained by the sand, which must then be renewed, or washed with fresh water, a process evidently useless for the purpose in question. This phenomenon, according to Berzelius, is due to the interstices between the grains of sand acting as capillary tubes; and as, at the beginning of the operation, the effect depends more on the attraction than on the pressure of the liquid poured in one of the branches of the tube, the salt is partly separated from the water which held it in solution, the latter lodging itself into the interstices of the sand, and filling them; if, when the mass of the sand is completely wetted, a greater quantity of sea water is poured upon it, the weight of the said sea water first displaces and expels the fresh water; but as soon as the interstices of the sand have thus been forcibly filled up with sea water, the water flowing at B becomes more and more salted; wherefore this filtration cannot yield more fresh water than can be contained in the interstices of a column of sand of a certain length, and proportionate to the saltness of the sea water.

Howbeit, the removal of the salt from sea water, so as to obtain fresh water therefrom, is, practically speaking, an impossibility, except by evaporation.

At first sight one would think that it is sufficient to submit sea water to distillation to convert it into fresh water, and that the solution of the problem is altogether dependent upon a still constructed so as to produce, by evaporation, a great quantity of distilled water, with a consumption of fuel sufficiently small to become practicable.

Distillation at a cheap rate is doubtless an important item, and fuel being a cumbrous and expensive article *on board ship*, it is superabundantly evident that, supposing all the apparatus which have hitherto been contrived for the purpose to answer equally well, that one would clearly merit the preference which would produce most at least cost; but there are, besides, other desiderata of a no less primary importance, and it is from having neglected, ignored, or been unable to realise them, that all the apparatus for obtaining fresh water from sea water, which have been from time to time brought before the public, have hitherto, without exception, proved total failures, or, after trial, have been quite discarded, or fulfil the object in view in a way so imperfect or precarious, that, practically speaking, the manufacture of fresh water at sea, or from sea water, may be said to have been, until quite lately, an unaccomplished feat. In order to understand the nature of the difficulties which stood in the way of success, a few words of explanation become necessary.

When ordinary water, whether fresh or salt, is submitted to distillation, the condensed steam, instead of being, as might be supposed, pure, tasteless, and odourless, yields on the contrary a liquid free from salt, it is true, but of an intolerably nauseous and empyreumatic taste and odour which it retains for many weeks; it is, moreover, insipid, flat, and vapid, owing to its want of oxygen and carbonic acid, which water in its natural state possesses, and of which it has been deprived by the process of distillation. In the absence of ordinary fresh water, this distilled water, however disagreeable and objectionable it may be, is of course of use so far as it is fresh, but the crews invariably refuse it as long as they can obtain a supply from natural sources.

With a view to remedy the defects just alluded to, various means have from time to time been proposed and employed: such as the addition of alum, sulphuric and other acids, chloride of lime, &c.; but it is evident that chemical reagents cannot effect the object; but if even they did, their use is always unsafe, for their continuous and daily absorption might, and doubtless would, cause accidents of a more or less serious nature, not to speak of the trouble and care required in making such additions. Liebig said, with both authority and reason, that, as a general rule, the use of chemicals should never be recommended for culinary (or food) purposes; for chemicals are seldom met with in commerce in a state of purity, and are frequently contaminated by poisonous substances. On the other hand, the percolation through perforated barrels or coarse sieves, porous substances, plaster, chalk, sand, &c., the pumps, ventilators, bellows, agitators, which have been proposed to aërate the distilled water obtained, and render it palatable, are slow in their action, of a difficult, inconvenient, or impossible application; and as to leaving the distilled water to become aërated by the agitation imparted to it in tanks or casks by the motion of the ship, this must be continued for a length of time, proportioned of course to the vigour of the oscillations imparted to the ship by the violence of the waves, and the time thus required is always considerable; yet in this way, and finally by pouring the water several times from one glass to another before drinking it, it may become fully aërated, but without entirely losing its vapid and nauseous taste and odour.

But before proceeding further, it may not be amiss to say a few words respecting another condition in the construction of marine condensing machines, which, from not being sufficiently taken into account, frequently puts them suddenly out of service, or necessitates constant repairs.

The question which had hitherto been left unanswered, and yet which must be integrally solved before success could be hoped for, is the following:—

To obtain, with a small proportion of fuel, large quantities of fresh, inodorous, salubrious, aërated water, without the help of chemical reagents, by means of a self-acting and compact apparatus capable of being worked at all hours, under all latitudes, in all weathers and conditions compatible with the existence of the ship itself, and incapable of becoming incrusted, or of otherwise going out of order.

How this complex and difficult problem was solved by Dr. Normandy we now proceed to explain:—

It is a known property of steam that it becomes condensed into water again, whenever it comes in contact with water at a temperature lower than itself, no matter how high the temperature of that condensing water may be.

It is known that the sea and other natural waters are saturated with air containing a larger proportion of oxygen and of carbonic acid than the air we breathe. In effect, 100 volumes of the air held in solution in water contain from 32 to 33 volumes of oxygen, whereas 100 volumes of ordinary atmospheric air contain only 24 volumes of oxygen. Again, ordinary atmospheric air contains only $\frac{1}{4000}$ of carbonic acid, whereas the air held in solution in water contains from 40 to 42 per cent. of carbonic acid.

Experiments undertaken with a view to determine the amount of these gases present in water, showed that this amount varied with the state of purity of the water; that whilst ordinary rain-water contains, on an average, 15 cubic inches of oxygenised air per gallon, it was constituted as follows:—

Carbonic acid	6·26
Oxygen	5·04
Nitrogen	3·70
	15·00

Sea water, owing to the various substances which it holds in solution, contains only on an average 5 cubic inches of gases, more than one-half of which is carbonic acid; or, in other words, 1 gallon of sea water contains about two-thirds less gases than ordinary rain-water, and one-half less gases than river water.

It has been ascertained that air begins to be expelled from such natural waters when the temperature reaches about 130° Fahr.; and we know that when the temperature reaches 212° Fahr., all the air which it contained has been expelled, and it is for this reason that distilled water contains no air.

The apparatus invented by Dr. Normandy is represented in *figs.* 2100, 2101. It consists of three principal parts—an evaporator, a condenser, and a refrigerator—joined so as to form one compact and solid mass, screwed and bolted, without soldering or brazing of any kind. The evaporator is a cylinder, partly filled with sea water, into which a sheaf of pipes is immersed, so that on admitting steam at a certain pressure into these pipes it is condensed into fresh, though non-aërated water by the sea water by which the pipes are surrounded, that sea water being thus heated and a portion of it evaporated at the same time; for it is one of the properties of steam to be condensed by water, no matter how high the temperature of that water may be, if it be only inferior to that of the steam. This non-aërated water becomes aërated, as will be explained below. On board steamers, the steam is obtained directly from the boilers of the ship; in sailing-vessels it is procured from a small boiler which may, or may not be connected with the hearth, galley, or caboose.

The steam at a pressure being, of course, hotter than ordinary boiling water, serves to convert a portion of the water contained in the evaporator into ordinary or non-pressure steam, which, as it reaches the pipes in the condenser, B, is resolved into fresh aërated water. By thus evaporating water under slight pressure, one fire performs double duty, and thus the first condition, that of economy, is completely fulfilled, for while, in the usual way, 1 lb. of coal evaporates at most 6 or 7 lbs. of water, the same quantity of coals, put under the same boiler, but in connection with this apparatus, is thus made to evaporate 12 or 14 lbs. of water; or, in other words, from the same amount of coals or of steam employed, the machine which is described will produce double the quantity of fresh water that can be obtained by simple or ordinary distillation; that is to say, double the quantity obtained by the ordinary condensers.

The comparative trials made in 1859 on board H.M. ships the Sphynx, Erebus, and Odin, at Portsmouth, before the Commissioners of the Admiralty, most conclusively proved the perfect accuracy of that statement.

The steam issuing from the evaporator, and which is condensed by the water in the condenser, imparts, of course, its heat to the sea water in it; and as this water is admitted cold at the bottom, whilst the steam of the evaporator is admitted at the top of the condenser, the water therein becomes hotter and hotter gradually as it ascends, and when it finally reaches the top its temperature is about 208° Fahr.

It has been already stated that water begins to part with its air at a temperature of about 130° Fahr., therefore the greater portion of the air contained in the water which flows constantly and uninterruptedly through the condenser is thus separated, and led through a pipe into the empty space left for steam-room within the evaporator, where it mixes with the steam.

Now, as about six gallons of sea water must be discharged for every gallon of fresh water which is condensed, and as each gallon of sea water contains, as was said before, 5 cubic inches of air, and whereas the utmost quantity of it that fresh water can naturally absorb is 15 cubic inches per gallon, it follows that the steam in the evaporator, before it is finally condensed, has been in contact with twice as much air as water can take up, the result being a production of fresh water to the maximum of aëration, that is, containing as much air as in pure rain-water.

This aëration of the water to the maximum and with the air naturally contained in the water in its original state, though a condition of the utmost importance, Dr. Normandy having failed in removing the odour and taste in question, it became necessary to try to discover whence came that flavour which no aëration could destroy, except after a considerable length of time, and even then never perfectly. That water has the power of absorbing and dissolving organic matter is, of course, well known, but it may be illustrated in a very simple manner, as follows :—If water, from whatever source, be distilled, the distillate will, of course, be fresh water, pure fresh water, but it will have a peculiar, nauseous, and empyreumatic taste and odour, stronger in proportion as the heat applied to evaporate it has been more elevated; it is that smell and taste which render it undrinkable for a while. If, when it has become sweet again by long standing, which period may be hastened by agitation in the atmosphere, that distilled water be then re-distilled, the distillate will be found to have acquired again the same empyreumatic taste and odour as when it was first distilled. How is this?—Because it will, by standing or agitation, have re-dissolved a portion of the air in the room in which it was kept, and along with that air it will have absorbed whatever substances were present, dissolved or suspended in it, and those substances by their contact with the heated surfaces of the still, yield an empyreumatic product, which taints the distillate. On board ships, the water which is stored in for the use of crews in the usual way, in the course of about a fortnight becomes putrid and almost undrinkable, because the organic matter which that water contains is undergoing putrefactive fermentation. But about a month or so afterwards the water gradually becomes sweeter and sweeter, until at last it becomes drinkable again; because, eventually, all the organic matter which it contained becomes decomposed, carbonic acid and water being the result, and although the air of a ship's hold is none of the sweetest, such water, as just said, generally remains afterwards perfectly good and palatable; because, the tanks in which it is kept, being covered up, it is sheltered from fresh pollutions, and because it is now saturated with pure air, and therefore cannot absorb that of the atmosphere.

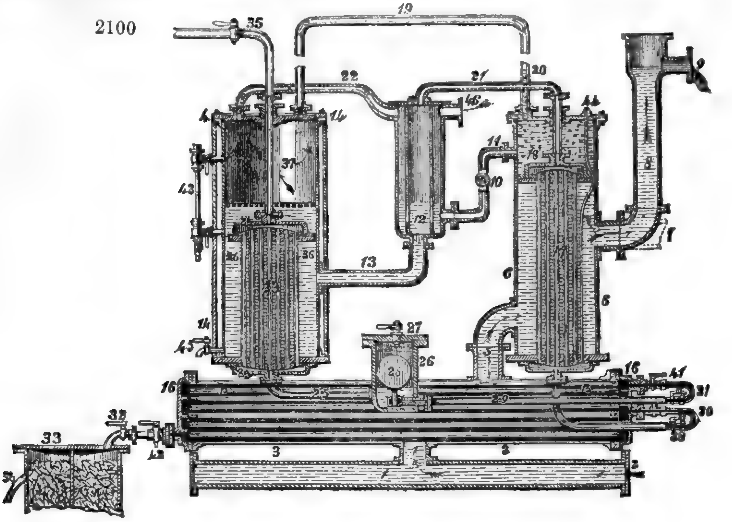
When the natural waters supplied to our habitations are obtained from impure sources, as is unfortunately too often the case, the evils resulting from their use may in some degree be remedied by putting in practice the recommendation which has been sometimes made, of boiling such water previous to employing it as a beverage; unfortunately, the water being thereby deprived of air is, like distilled water, though in a less degree, unpalatable and vapid and heavy; it is, in fact, of difficult digestion; but there is something worse than that; water which has been boiled, or which has been distilled, by reason of its containing *no air*, has a great tendency to absorb or to take that of the media where it is kept, so that if distilled water which contains no air be kept in a ship's hold, or in an impure and confined place, it will absorb precisely the quantity of air which it can absorb, namely, 15 cubic inches per gallon, and if that air be loaded with organic particles or impure emanations, it will soon become fœtid and putrid. The experiments of Dr. Angus Smith have proved that if a stream of air which has already been breathed be passed through water, the latter will retain a peculiar albuminoïd matter which undergoes putrefaction with extraordinary rapidity; and the water which condenses on the cold exterior surfaces of vessels in crowded rooms possesses the same character, and acquires in a short time an offensive odour; now this is to a great extent the case with the water of ordinary condensers when allowed to become spontaneously aërated on board ship. Thus water, though distilled, if kept in tainted rooms, will soon become foul. The only condition necessary for distilled water not to become putrid or offensive is to saturate it with *pure air*, because in that case there is no room left for other gases to impregnate it (at least, practically speaking, and in the ordinary conditions of domestic or of ship economy) and to keep it in covered vessels or tanks.

Fig. 2100 is a section, all on the same plane, showing the mode of action of the apparatus, without reference to the real position of its constituent parts. *Fig.* 2101 is a correct front elevation of the apparatus.

1 shows the large entrance tube for the sea water: this tube is connected to a large cock, communicating with the sea through the side or bottom of the ship; or else flanged to a much smaller pipe connected with a pump, by means of which the apparatus is supplied with water from the sea, which thus penetrates into the refrigerator 3, through the tube of communication 4, and thence passes round the sheaf of pipes 15, in the said refrigerator, through another communication tube 5, into the condenser 6, as shown by the arrows, and up the large vertical tube 8, whence the surplus sea water pumped up flows away through the pipe 9, in the direction indicated by the arrows. The condenser, 6, being thus completely filled up with sea water, on opening the cock 10, the sea water passing through pipe 11 falls into the feed and priming box 12, and thence through pipe 13 into the evaporator 14, filling it up to a certain level, regulated by opening or shutting the cock 10 so as to maintain the sea water at the proper level in the evaporator 14.

3, *Refrigerator.* It is a horizontal case pervaded with pipes 15, placed horizontally in it. The sea water being introduced into this refrigerator, circulates round a sheaf of pipes 15, held between the caps 16, at each end of the said refrigerator, so that the fresh water which has been condensed in the pipes 23, of the evaporator 14, and in the pipes 17 of the condenser 6, is thereby cooled down to the temperature of the sea water outside.

2100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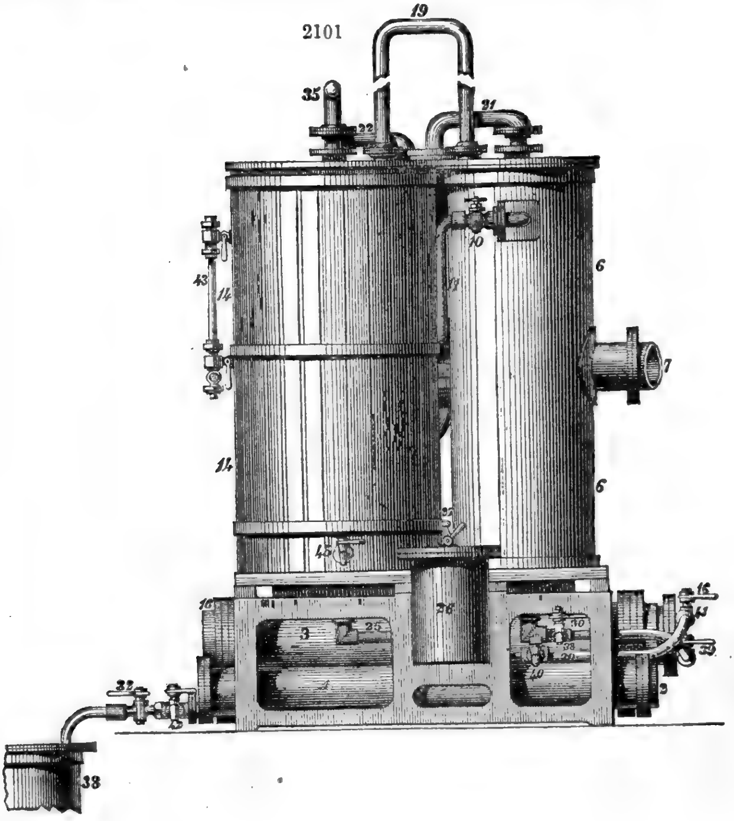
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4, large pipe connecting the pipe 1 with the refrigerator 3.

5, large pipe connecting the refrigerator 3 with the condenser 6.

6, *Condenser.* It is a cylinder containing a sheaf of pipes 17, into which the non-aërated steam from the evaporator is condensed by the sea water which surrounds them.

7, large outlet tube, used only when the apparatus is put below the level of the sea.

8, large upright tube, which, when the apparatus is placed on deck is turned upwards, and is of such a length that the sea water which is forced through the apparatus by means of the pump, or otherwise, may be raised a few feet above the whole apparatus, so that there may be in the large tube 8, a column of sea water higher than the condenser 6, in order to keep it quite full.

9, overflow pipe for the escape of the excess of sea water.

10, cock of the feed pipe.

11, feed pipe, one end of which is inserted in the condenser 6, and the other end in the feed and priming box 12. It is through this feed pipe 11, that the sea water is led from the top of the condenser into the feed and priming box 12, by opening the cock 10 to a suitable degree, as said before 1.

12, feed and priming box. It is a box into which, on opening the cock 10, the sea water supplied from the condenser 6, by pipe 11, passes through pipe 13 into the evaporator 14, which is thus fed with the proper quantity of sea water. This feed box receives also any priming which might be mechanically projected by or carried along with the steam through pipe 22. In such a case the priming is then returned to the evaporator 14, through pipe 13.

13, feed-pipe leading to the sea water to be evaporated in the evaporator 14.

14, *Evaporator.* It is a cylinder containing a sheaf of pipes 23, with their caps, 24, at each end, immersed in the sea water, part of which is to be evaporated.

15, sheaf of pipes of the refrigerator 3, for the purpose of cooling the fresh water produced; has been already described under No. 3.

16, caps of the refrigerator 3, so arranged that by means of the divisions reserved in the said caps, the steam from the boiler, and that evolved from the evaporator 14, are both made to travel to and fro through the different pipes 15 consecutively, so as eventually to flow out in a mixed and cold state through the cock 32 in the filter 33, and finally through the tube 34 in a perfect state.

17, sheaf of pipes placed between the two caps 18 of the condenser 6, for the purpose of condensing the aërated steam from the evaporator 14.

18, caps covering the end of the sheaf of pipes 17 placed in the condenser 6.

19, aërating pipe leading the air which separates from the sea water round the pipes 17 of the condenser 6 into the steam-room or chamber of the evaporator 14. It is by means of this aërating pipe that the fresh water condensed in the condenser 6 becomes aërated, and this aëration is accomplished as follows:—

As the steam from the evaporator 14 enters the pipes within the condenser 6 at the top thereof, through the pipe 21, it follows that the sea water at the top of the condenser 6 is brought, as was already said under No. 11, to a temperature which, at the top of the said condenser, is as high as 206° or 208° Fahr.; this temperature, as we also said of No. 11, gradually diminishes from the top downwards, but at a zone corresponding to about the point marked by No. 7, the temperature of the sea water round the sheaf of pipes 17 is reduced to about 140° Fahr. As the air naturally contained in sea water begins to separate therefrom at about 130° Fahr., that in the sea water round the sheaf of pipes 17, between No. 7 and the top of the condenser, becoming entirely liberated, ascends, by virtue of its lighter weight, to the top of the said condenser 6; it then passes through the aërating pipe 19, and is then poured into the steam-room 37 of the evaporator 14, wherein it mixes with the secondary steam therein produced by the evaporating pipes 23. This mixture of air and steam passes then through pipes 22 into the feed and priming-box 12, and thence through pipe 21 into the sheaf of pipes 17. The air being there absorbed during the condensation of this secondary steam, with which it was mixed, the condensed fresh water resulting therefrom becomes thus super-aërated, and in passing subsequently through the cock 39 of pipe 30 into a portion of the pipes 15 of the refrigerator 3, it mixes there with the non-aërated fresh water, resulting from the steam of the boiler, which has condensed in the pipes 23 of the evaporator 14, which condensed water flows through pipe 25 into the steam-trap 26, thence along pipes 29 and 31, and through the cock 41, into the other portion of pipes 15 of the refrigerator 3. The condensed water from the pipes 23 of the evaporator 14 becomes aërated by the excess of air contained in the condensed water of the pipes 17 of the condenser, in its passage with the latter through the pipes 15 of the refrigerator 3, in traversing which the combined waters are cooled down to the temperature of the sea water round the said sheaf of pipes in the refrigerator. And the result is, that after passing through the filter it flows at 34 in the state of perfectly cold fresh water, thoroughly aërated, and of matchless quality.

20, level to which the sea water rises in the aërating pipe 19.

21, pipe conducting the mixture of steam and air from the feed and priming-box 12 into the sheaf of pipes 17 of the condenser 6.

22, pipe leading the mixture of steam and air from the evaporator 14 into the feed and priming-box 12, where any salt water, with which it may be mixed, is arrested and returned to the evaporator 14, through pipe 13, while the pure steam, passing through pipe 21, is next condensed in the sheaf of pipes 17 of the condenser 6.

23, sheaf of pipes immersed in the sea water 36 of the evaporator 14, and in which pipes the steam coming from the boiler through the steam-pipe 35 is condensed, after which it flows as distilled but *non-aërated* fresh water into the lower cap 24, and thence through pipe 25 into the steam-trap 26, thence through the pipes 29 and 31 and cock 41 into the sheaf of pipes 15 of the refrigerator 3.

24, upper and lower caps covering the two extremities of pipes 23 of the evaporator 14, into which pipes the steam from the boiler diffuses itself, and is condensed, after which it flows in the state of distilled but non-aërated fresh water, through pipe 25 into the steam-trap 26. and thence through pipes 29 and 31 into the pipes 15 of the refrigerator 3, in which it mixes with the *aërated* water coming through pipe 30, and passing through pipe 32 into the filter 33, finally issues at pipe 34 in the state of cold, matchless, aërated fresh water, *immediately fit for consumption.*

25, pipe for the exit of the condensed non-aërated fresh water from the sheaf of pipes 23, of the evaporator 14, which water, after entering the steam-trap 26, issues therefrom through pipe 29, and then enters the refrigerator as already said.

26, steam-trap. It is a box containing a float 28, provided with a plunger acting in such a way that when the box contains only steam, or a quantity of condensed water, not sufficient to buoy the float, it (the plunger) closes the exit pipe 29; but as soon as the condensed water has accumulated in quantity sufficient to buoy the float up, the plunger, of course, rising with the float, no longer obstructs the exit pipe 29, and accordingly the condensed water may then escape as fast as it is produced.

27, small pet cock on the top of the cover of the steam-trap 26.

28, float already described (26).

29, pipe leading the condensed non-aërated water from the steam trap 26, through pipe 31, into the pipes 15 of the refrigerator 3, in which it mixes with the aërated fresh water from the condenser.

30, pipes leading the condensed aërated water from the pipes 17 of the condenser 6, into the pipes 15 of the refrigerator 3, in which it mixes with the non-aërated water from the steam.26. This pipe is provided with two cocks, 38 and 39, for the purpose of cleaning the condenser 6.

31, pipe leading the condensed non-aërated water from pipe 29 into the pipes 15 of the refrigerator, in which it mixes with the aërated water from the condenser.

32, exit-pipe and cock, through which the mixed distilled waters (aërated and non-aërated), after passing through the pipes of the refrigerator, enter the filter 33.

33, filter for receiving the condensed water from both the evaporator and the condenser, as they issue in a mixed and cold state from the pipes 15 of the refrigerator 3, through cock and pipe 32.

34, pipe for the final exit of the perfect aërated fresh water.

35, steam-pipe and cock leading the steam more or less under pressure from any description of boiler to the pipes 23 of the evaporator 14. It is connected at one end with the steam-boiler, and at the other with the upper cap, 24, of the evaporating pipes 23.

36, sea water, to be evaporated by the steam-pipes 23, of the evaporator 14.

37, steam room, or space into which the air naturally contained in the sea water used for condensation in the condenser 6, is poured through the aërating pipe 19, so as to mix with the steam generated by the pipes 23 of the evaporator.

38 and 39, two cocks on pipe 30, placed between the condenser 6 and the refrigerator 3, for the purpose of clearing the pipes 17 of the condenser 6.

40 and 41, two cocks placed on pipe 31, for the purpose of clearing the pipes 23 of the evaporator 14, and steam-trap 26.

42, cock placed between the cap 16 of the refrigerator 3, and the cock 32, for the purpose of cleaning the pipes 15 of the refrigerator 3.

43, glass water-gauge.

44, breathing-pipe. It is a small pipe, one end of which is in communication with the lower cap 18 of the condensing-pipes 17, and the other end is open to the atmosphere. The object of this pipe is not only to remove pressure from the cylinders, but likewise to afford an exit for the excess of air generated.

45, brine cock.

46, opening reserved in the feed and priming-box.

The first thing to be done is, of course, to charge the apparatus with sea water. This is done by establishing a communication between the apparatus and the sea water round the ship. This is easily effected by turning on the large cocks, or Kingston valves, connected with the large orifices 2 and 7 (see the figures), whereupon the salt water immediately fills up both the refrigerator 3 through the passage 4 and the condenser 6 through the passage 5, up to a certain point 20 of the aërating pipe.

Opening now the cock 10 of the feed pipe 11 the sea water will pass from the condenser 6 into the feed and priming-box 12 and thence through pipe 13 into the evaporator 14, where it should be allowed to rise up to about one third of the glass gauge, 43, when the cock 10 should be shut up. The apparatus being thus charged with its proper quantity of sea water; the steam-boiler being ready to furnish the necessary steam; and admitting, of course, that the steam-pipe 35 is in communication with the said boiler, the next thing to be done is to open the steam-cock, 35, shutting at the same time the cocks, 39, 41, and 32, and opening cocks, 38, 40, and 42, and likewise the small pet cock 27 of the steam-trap 26. On opening the small pet cock 27 nothing but air will at first rush out; but, presently, steam will issue from it; it should then be closed more and more gradually as the steam is seen issuing from it with rapidity; and it should eventually be left *almost*, but not altogether, shut up, so as to leave only room for the smallest possible wreath of steam slowly to issue from it. As soon as the steam-cock 35 is open, and the steam from the boiler will rush through that cock into the sheaf of pipes 23 of the evaporator 14, in which pipes it will be condensed by the sea water which surrounds them, and it will then flow in the state of condensed non-aërated distilled water through the pipe 25 into the steam-trap 26; lift up the float 22, and passing through pipe 29, will flow through cock 40, its further progress being intercepted by cock 41, which is shut, as said before. As soon as the condensed water flows out in a clear state from cock 40, shut it, and open cock 41, so that it may pass into the pipes 15 of the refrigerator 3, and out at cock 42. In a few moments the condensed water will flow out in a clear state from that cock, 42, which should then be closed, opening at the same time cock 32, so that it may pass into the filter 33.

But the steam within the sheaf of pipes 23 of the evaporator 14 soon brings the sea water round them to the boiling point, and converts part of it into steam. This pure secondary steam from the evaporator, issuing then from the priming-box 12, passes through pipe 21 into the pipes 17 immersed in the salt water of the condenser 6, and being condensed in the said pipes, is allowed to flow out at the cock 38 (which has been opened at starting), as long as it is not clear. In a short time, however, it will flow out from that cock 38, in a perfectly clear state; when this takes place shut this cock 38, and open cock 39, whereupon it will flow into the pipes 15 of the refrigerator 3, in which pipes it will mix with that coming from the pipes 23 of the evaporator 14, and flow with it through the said pipes 15, and thence into the filter 33 through the cock 32, the whole issuing finally from the filter 33 through pipe 34, in the state of perfectly aërated fresh water.

From this brief description of Dr. Normandy's marine fresh-water apparatus it may be seen that a quantity of fresh water is produced *always double* that which can be evaporated from any boiler whatever, and indeed by increasing the number of evaporators 1 lb. of coals may thus be made to yield 30 or 40 lbs. of fresh water of matchless quality. The small volume of the apparatus, the large quantity of fresh aërated water which it produces, at an extremely small cost, its perfect safety, permanent order, and the ease with which it can be disconnected, and all its parts reached, not only render it pre-eminently suited to naval purposes, but likewise to such stations or places as are deficient in one of the first necessaries of life, salubrious fresh water, or where it cannot be obtained at all, or only in an insufficient, precarious, or expensive manner.

WATTLE BARK. See BARK.

WAX (*Cire*, Fr.; *Wachs*, Ger.) is the substance which forms the cells of bees. It was long supposed to be derived from the pollen of plants, swallowed by these insects, and merely voided under this new form; but it has been proved by the experiments, first of Mr. Hunter, and more especially of M. Huber, to be the peculiar secretion of a certain organ, which forms a part of the small sacs situated on the sides of the median line of the abdomen of the bee. On raising the lower segments of the abdomen these sacs may be observed, as also scales or spangles of wax, arranged in pairs upon each segment. There are none, however, under the rings of the males and the queen. Each individual has only eight wax sacs, or pouches; for the first and the last wing are not provided with them. M. Huber satisfied himself by precise experiments that bees, though fed with honey or sugar alone, produced nevertheless a very considerable quantity of wax; thus proving that they were not mere collectors of this substance from the vegetable kingdom. The pollen of plants serves for the nourishment of the larvæ.

But wax exists also as a vegetable product, and may, in this point of view, be regarded as a concrete fixed oil. It forms a part of the green fecula of many plants, particularly of the cabbage; it may be extracted from the pollen of most flowers, as also from the skins of plums and many stone-fruits. It constitutes a varnish upon the upper surface of the leaves of many trees, and it has been observed in the juice of the *cow-tree*. The berries of the *Myrica angustifolia*, *M. latifolia*, as well as the *M. cerifera*, afford abundance of wax.

Bees' wax, as obtained by washing and melting the comb, is yellow. It has a peculiar smell, resembling honey, and derived from it, for the cells in which no honey has been deposited yield a scentless white wax. Wax is freed from its impurities, and bleached, by melting it with hot water or steam, in a tinned-copper or wooden vessel, letting it settle, running off the clear supernatant oily-looking liquid into an oblong trough with a line of holes in its bottom, so as to distribute it upon horizontal wooden cylinders made to revolve half immersed in cold water, and then exposing the thin ribbons or films thus obtained to the blanching action of air, light, and moisture. For this purpose the ribbons are laid upon long webs of canvas stretched horizontally between standards, 2 feet above the surface of a sheltered field, having a free exposure to the sunbeams. Here they are frequently turned over, then covered by nets to prevent their being blown away by winds, and watered from time to time, like linen upon the grass field in the old method of bleaching. Whenever the colour of the wax seems stationary, it is collected, re-melted, and thrown again into ribbons upon the wet cylinder, in order to expose new surfaces to the bleaching operation. By several repetitions of these processes, if the weather proves favourable, the wax eventually loses its yellow tint entirely, and becomes fit for forming white candles. If it be finished under rain, it will become grey on keeping, and also lose in weight.

In France, where the purification of wax is a considerable object of manufacture, about 4 ounces of cream of tartar or alum are added to the water in the first melting-copper, and the solution is incorporated with the wax by diligent manipulation. The whole is left at rest for some time, and then the supernatant wax is run off into a settling cistern, whence it is discharged by a stopcock or tap over the wooden cylinder revolving at the surface of a large water-cistern, kept cool by passing a stream continually through it.

The bleached wax is finally melted, strained through silk sieves, and then run into circular cavities in a moistened table, to be cast or moulded into thin disk pieces, weighing from 2 to 3 ounces each, and 3 or 4 inches in diameter.

Neither chlorine nor even the chlorides of lime and alkalis can be employed with any advantage to bleach wax, because they render it brittle, and impair its burning quality.

Wax purified as above is white and translucent in thin segments; it has neither taste nor smell; it has a specific gravity of from 0·960 to 0·996; it does not liquefy till heated to 154½° Fahr.; but it softens at 86°, becoming so plastic that it may be moulded by the hand into any form. At 32° it is hard and brittle.

It is not a simple substance, but consists of two species of wax, which may be easily separated by boiling alcohol. The resulting solution deposits, on cooling, the waxy body called *cerine*. The undissolved wax being once and again treated with boiling alcohol, finally affords from 70 to 90 per cent. of its weight of cerine. The insoluble residuum is the *myricine* of Dr. John, so called because it exists in a much larger proportion in the wax of the *Myrica cerifera*. It is greatly denser than wax, being of the same specific gravity as water; and may be distilled without decomposition, which cerine undergoes. Professor B. C. Brodie made an extensive series of researches into the constitution of wax. He applies the name *cerotic acid* to cerine, and represents its formula as $C^{54}H^{54}O^{4}$ ($\mathbf{C^{27}H^{54}O^{2}}$). Pure myricine he considers to be represented by $C^{92}H^{92}O^{4}$ ($\mathbf{C^{46}H^{92}O^{2}}$). Myricine is a palmitate of myricyl.

Wax is adulterated sometimes with starch; a fraud easily detected by oil of turpentine, which dissolves the former and leaves the latter substance: and more frequently with mutton-suet. This fraud may be discovered by dry distillation; for wax does not thereby afford, like tallow, sebasic acid (benzoic), which is known by its occasioning a precipitate in a solution of acetate of lead. It is said that 2 per cent. of a tallow sophistication may be discovered in this way.

Wax is sometimes adulterated with stearine, which can be detected, according to Lebel, even when only in 1–20th part. It may be recognised by dissolving the specimens in two parts of oil, agitating with water, and adding acetate of lead. The precipitate thus obtained is said to exhibit a very high degree of solidity.

Wax *Imported* in 1873:—42,689 tons; value, 221,951*l*.

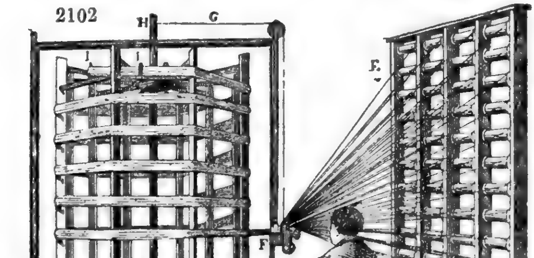
Wax *Exported* in 1873:—20,260 cwts.; value, 104,600*l*.

WAX CANDLES. Wax contains 81·75 parts of carbon in 100, which generate by combustion 300 parts of carbonic acid gas. Now, since 125 grains of wax constitute the average consumption of a candle per hour, these will generate 375 grains of carbonic acid; equivalent in volume to 800 cubic inches of gas. According to the most exact experiments on respiration, a man of ordinary size discharges from his lungs 1,632 cubic inches of carbonic acid gas per hour, which is very nearly the double of the quantity produced from the wax candle. Hence the combustion of two such candles vitiates the air much the same as the breathing of one man. A tallow candle, three or four in the pound, generates nearly the same quantity of carbonic acid as the wax candle; for though tallow contains only 79 per cent. of carbon, instead of 81·75, yet it consumes so much faster, as thereby to compensate fully for this difference.

When a tallow candle of 6 to the lb. is not snuffed, it loses in intensity, in 30 minutes, 80-hundredths, and in 39 minutes, 86-hundredths; in which dim state it remains stationary, yet still consuming nearly the same proportion of tallow. A wax candle attains to its greatest intensity of light when its wick has reached the greatest length, and begins to bend out of the flame. The reason of this difference is, that only the lower part of the wick in the tallow candle is charged with the fat, so as to emit luminiferous vapour, while the upper part remains dry; whereas, in the wax candle the combustible substance being less fusible and volatile, allows a greater length of the wick to be charged by capillary attraction, and of course to emit a longer train of light.

WEAVING (*Tissage*, Fr.; *Weberei*, Ger.) is performed by the implement called *loom* in English, *métier à tisser* in French, and *Weberstuhl* in German. The process of warping must always precede weaving. Its object is to arrange all the longitudinal threads, which are to form the chain of the web, alongside of each other in one parallel plane. Such a number of bobbins, filled with yarn, must therefore be taken as will furnish the quantity required for the length of the intended piece of cloth. One-sixth of that number of bobbins is usually mounted at once in the warp mill, being set loosely in a horizontal direction upon wire-skewers, or spindles, in a square frame, so that they may revolve, and give off the yarn freely. The warper sits at A, *fig.* 2102, and causes the reel B to revolve, by turning round with his hand the wheel B, with the endless rope or band D. The bobbins filled with yarn are placed in the frame E. There is a sliding piece at F, called the *heck* box, which rises and falls by the coiling and uncoiling of the cord G, round the central shaft of the reef H. By this simple contrivance the band of warp-yarns is wound spirally from top to bottom upon the reel. I, I, I, are wooden pins which separate the different bands. Most warping-mules are of a prismatic form, having twelve, eighteen, or more sides. The reel is commonly about 6 feet in diameter and 7 feet in height, so as to serve for measuring exactly upon its periphery the total length of the warp. All the threads from the frame E pass through the heck F, which consists of a series of finely-polished, hard-tempered steel pins, with a small hole at the upper part of each to receive and guide one thread. The heck is divided into two parts, either of which may be lifted by a small handle below, while their eyes are placed alternately. Hence, when one of them is raised a little, a vacuity is formed between the two bands of the warp; but when the other is raised, the vacuity is reversed. In this way the lease is produced at each end of the warp, and it is preserved by appropriate wooden pegs. The lease being carefully tied up affords a guide to the weaver for inserting his lease-rods. The warping-mill is turned alternately from right to left, and from left to right, till a

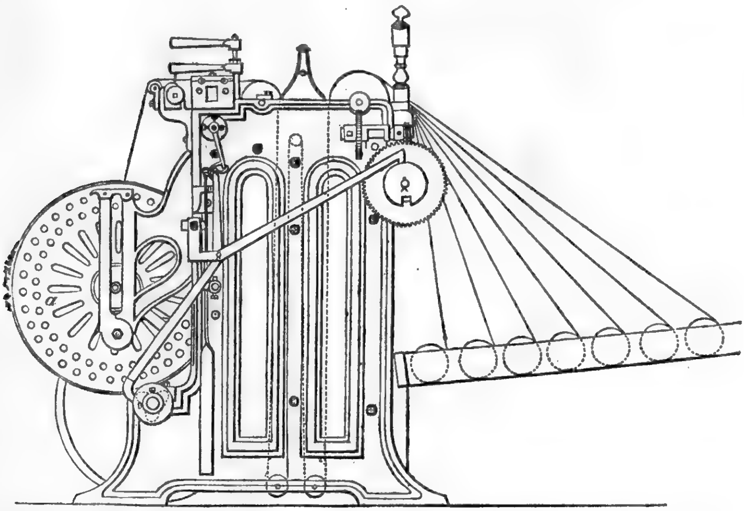
2102



sufficient number of yarns are coiled round it to form the breadth that is wanted; the warper's principal care being to tie immediately every thread as it breaks, otherwise, deficiencies would be occasioned in the chain, injurious to the appearance of the web, or productive of much annoyance to the weaver.

Fig. 2103 shows another form of warping-mill, known as the beam-warping machine, and generally in use for yarns above 20*s.* in counts, as by its use more perfect work can be produced, and at a less cost than on the vertical warping-mill. It is supplied with a letting-back motion, whereby, when a thread is broken, the motion of the winding-on beam, or drum, is reversed, and by the aid of a simple arrangement of falling iron rods, the thread may be easily found and reunited. It has also a self-acting measuring and stopping motion, by means of which the machine is promptly stopped the moment the proper length of yarn is wound on to the weavers' warp-beam. The drum on which the weavers' beam revolves, is so constructed as to suit any length of beam, by being expanded or contracted. A comb or raithe, on the expanding or contracting principle, guides the threads with precision on to any length of beam. As a rule, young women are preferred to men for working this machine.

2103

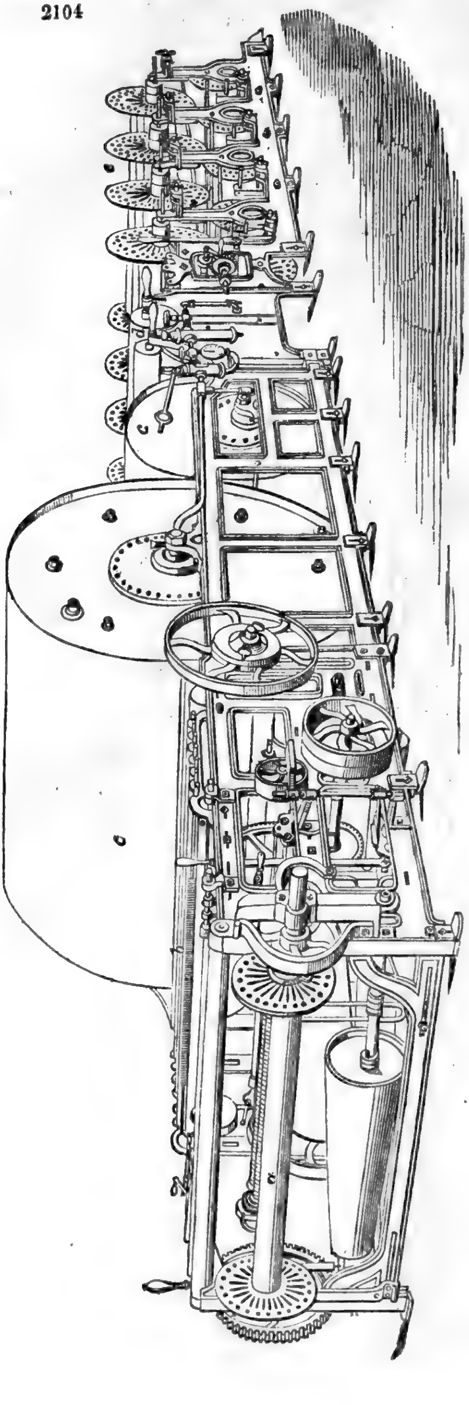


When a warp has been made, it requires to be sized before it is ready for the loom; for that purpose, it is taken as a ball from the vertical warping-mill, *fig.* 2102, and sized in a sizing-trough, and then dried by being passed over a number of hot cylinders, when it is wound by the beamer into the weavers' beam, and then, having been drawn in or twisted in to the healds and reeds, is ready for the loom.

In the case of a warp made in the horizontal or beam-warping machine, it is at once wound on a beam, and thence taken to the slasher sizing-machine, where, forming one of six or eight beams, its yarn is passed through the operations of sizing and drying, in one passage, and at once wound on to the weavers' beam, and is then ready to have attached the healds and reeds in the ordinary manner.

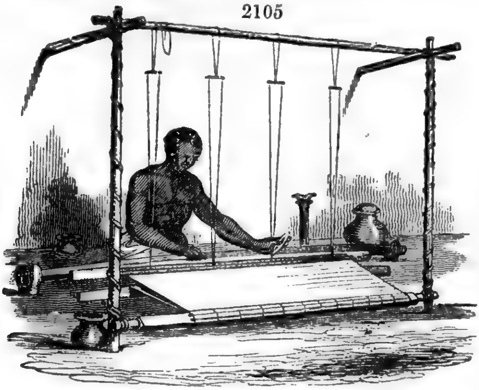
Fig. 2104 shows the slasher sizing-machine, as made by Messrs. Harrison and Sons, machinists, Blackburn. This machine is sufficient to size for 300 shirting-looms, and is managed by one man. The yarn is taken from the weavers' (8) beams shown in *fig.* 2103, and passed through boiling size, and then over the two cylinders, which are heated by steam, and having been dried by them, is at once wound on to the weavers' beam. The stand on which the warpers' beams are placed, is made so as to be adjustible to any length of beam. The flanges of the beams are of lined iron, and are convex on the inner side, to allow the yarn to leave the beam freely. The boiling box through which the yarn passes, is lined with copper to prevent oxidisation. The rollers in the box are hooped at the ends with brass, and run upon brass pullies, thus saving the roller ends, and producing a smooth motion. The size roller, or squeezer, is of heavy copper, without a seam, being cast solid, afterwards bored, and then expanded on a mandril to the proper diameter. By being made seamless, the acid in the size does not effect any brazed part, and by being thick and heavy, the rollers last longer and squeeze better. The machine is supplied with an apparatus which prevents any undue tension on the yarn while in a wet state; the elasticity of the yarn is thus retained, and broken threads in weaving largely prevented, thus securing quantity and quality in the loom. By the introduction of syphon-boxes and a self-acting apparatus to admit only a definite and certain quantity of steam into the cylinders, economy is effected in the consumption of steam. The machine *itself* gives notice, by ringing a bell, when a given length of yarn is sized, and also marks the length of a cut: an expanding comb guides the even and sheet-like threads on to the weavers' beam.

2104



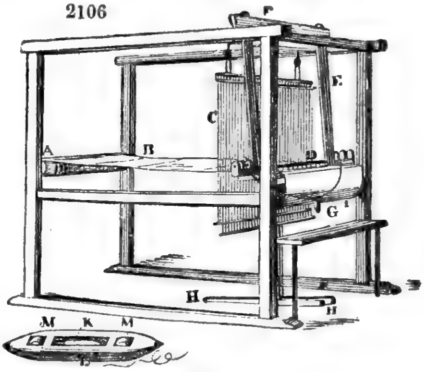
The simplest and probably the most ancient of looms now to be seen in action is that of the Hindú *tanty*, shown in *fig.* 2105. It consists of two bamboo rollers: one for the warp, and another for the woven cloth; with a pair of heddles, for parting the warp, to permit the weft to be drawn across between its upper and under threads. The shuttle is a slender rod, like a large netting-needle, rather longer than the web is broad, and is made use of as a batten or lag, to strike home or condense each successive thread or weft, against the closed fabric. The Hindu carries this simple implement, with his water pitcher, rice pot, and hooka, to the foot of any tree which can afford him a comfortable shade; he there digs a large hole, to receive his legs, along with the traddles or lower part of the harness; he next extends his warp, by fastening his two bamboo rollers at a proper distance from each other, with pins, into the sward; he attaches the heddles to a convenient branch of the tree overhead: inserts his great toes into two loops under the gear, to serve him for treddles; lastly, he sheds the warp, draws through the weft, and beats it close up to the web with his rod shuttle or batten.

2105



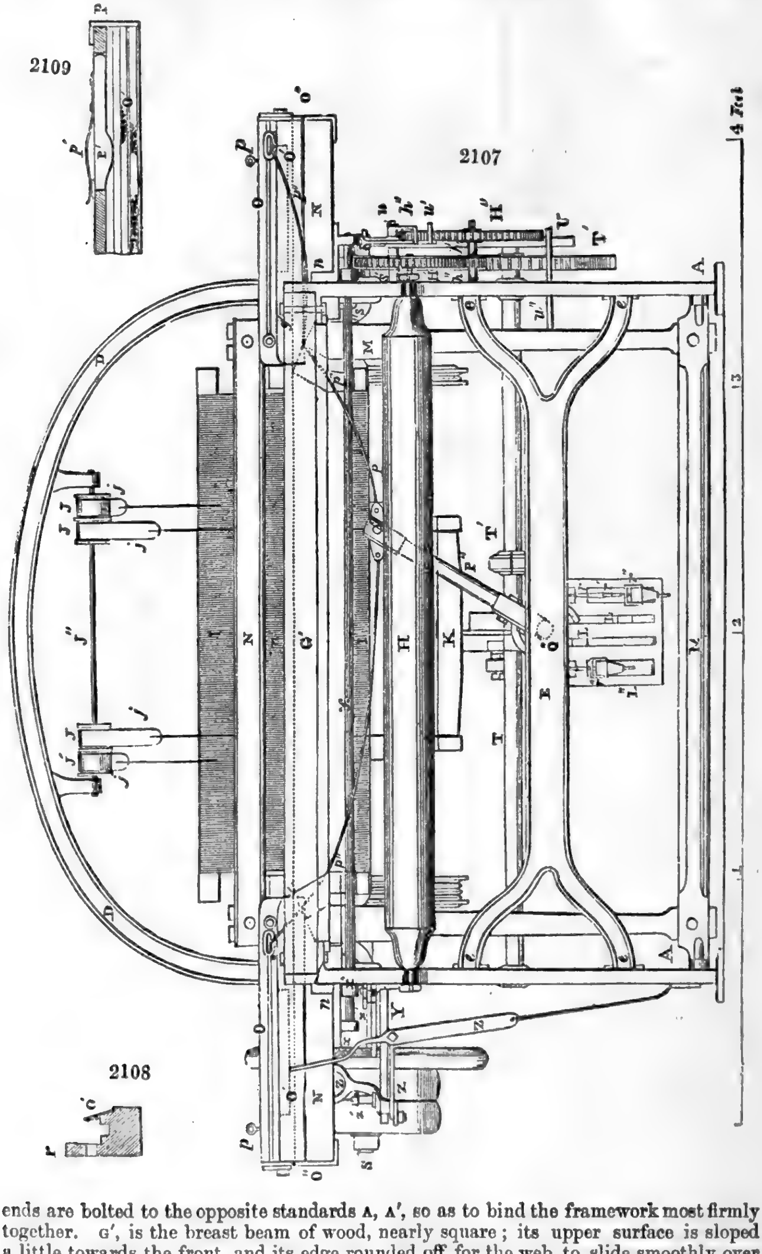
The European loom is represented in its plainest state, as it has existed for several centuries, in *fig.* 2106. A is a warp-beam, round which the chain has been wound; B represents the flat rods, usually three in number, which pass across between its threads, to preserve the lease, or the plane of decussation for the weft; C shows the heddles or healds, consisting of twines looped in the middle, through which loops the warp-yarns are drawn, one-half through the front heddle, and the other through the back one; by moving which, the decussation is readily effected. The yarns then pass through the dents of the reed under D, which is set in a moveable swing-frame E, called the lathe, lay, and also batten, because it *beats* home the weft to the web. The lay is freely suspended to a cross-bar F, attached by rulers, called the *swords*, to the top of the lateral standards of the loom, so as to oscillate upon it. The weaver, sitting on the bench G, presses down one of the treddles at H, with one of his feet, whereby he raises the corresponding heddle, but sinks the alternate one; thus sheds the warp, by lifting and depressing each alternate thread through a little space, and opens a pathway or race-course for the shuttle to traverse the middle of the warp, upon its two friction rollers M M. For this purpose, he lays hold of the picking-peg in his right hand, and with a smart jerk of his wrist drives the fly-shuttle swiftly from one side of the loom to the other, between the shed warp-yarns. The shoot of weft being thereby left behind from the shuttle pirn or cop, the weaver brings home, by pulling the lay with its reed towards him by his left hand, with such force as the closeness of the texture requires. The web, as thus woven, is wound up by turning round the cloth beam I, furnished with a ratchet-wheel, which takes into a holding-tooth. The plan of throwing the shuttle by the picking-peg and cord, is a great improvement upon the old way of throwing it by hand. It was contrived upwards of a century ago, by John Kay, of Bury, in Lancashire, but then resident in Colchester, and was called the 'fly-shuttle,' from its speed, as it enabled the weaver to make double the quantity of narrow cloth, and much more broad cloth, in the same time.

2106



The cloth is kept distended during the operation of weaving, by means of two pieces of hard wood, called 'a templet,' furnished with sharp iron points in their ends, which take hold of the opposite salvages or lists of the web. The warp and web are kept longitudinally stretched by a weighted cord, which passes round the warp-beam, and which tends continually to draw back the cloth from its beam, where it is held fast by the ratchet-tooth. See FUSTIAN, JACQUARD LOOM, REED, and TEXTILE FABRICS.

The greater part of plain weaving, and much even of the figured, is now performed by the power-loom, called *métier mécanique à tisser* in French. *Fig.* 2107, represents the cast-iron power-loom of Sharp and Roberts. A, A′, are the two side uprights, or standards, on the front of the loom, D, is the great arch of cast iron which binds the two sides together. E, is the front cross-beam, terminating in the forks *e*, *e*; whose


2109

2107

2108

ends are bolted to the opposite standards A, A′, so as to bind the framework most firmly together. G′, is the breast beam of wood, nearly square; its upper surface is sloped a little towards the front, and its edge rounded off for the web to slide smoothly over it in its progress to the cloth beam. The beam is supported at its end upon brackets, and is secured by the bolts *g*′, *g*′. H, is the cloth beam, a wooden cylinder mounted with iron gudgeons at its ends, that on the right hand being prolonged to carry the tooth winding wheel H′. *k′*, is a pinion in gear with H′. H″, is a ratchet-wheel, mounted upon the same shaft *h‴*, as the pinion *h′*. *h″*, is the click of the ratchet-wheel H″. *h‴*, is a long bolt fixed to the frame, serving as a shaft to the ratchet-wheel H″, and the pinion *h′*. I, is the front heddle-leaf, and I′, the back one. J, J, J′, J′, jacks or pulleys and straps for raising and depressing the leaves of the heddles. J″, is the iron shaft which carries the jack or system of pulleys, J, J, J′, J′. K, a strong wooden ruler, connecting the front heddle with its treddle. L, L′, the front and rear marches or treddle pieces for depressing the heddle-leaves alternately, by the intervention of the rods *k* (and *k′*, hid behind *k*). M, M, are the two swords (swing bars) of the lay or batten. N, is the upper cross-bar of the lay, made of wood, and supported upon the squares of the levers *n*, *n′*, to which it is firmly bolted. N′, is the lay-cap, which is placed higher or lower, according to the breadth of the reed; it is the part of the lay which the hand-loom weaver seizes with his hand, in order to swing it towards him. *n′*, is the reed contained between the bar N, and the lay-cap N′. O, O, are two rods of iron, perfectly round and straight, mounted near the ends of the batten-bar N, which serve as guides to the drivers or peckers *o*, *o*, which impel the shuttle. These are made of buffalo-hide, and should slide freely on their guide-rods. O′, O′, are the fronts of the shuttle-boxes; they have a slight inclination backwards; P is the back of them. (See *figs.* 2108 and 2109.) O″, O″, are iron plates, forming the bottom of the shuttle-boxes. *p*, small pegs or pins, planted in the posterior faces P (*fig.* 2107) of the boxes, round which the levers P′ turn. These levers are sunk in the substance of the faces P, turned round pegs *p*, being pressed from without inwards, by the springs *p′*. P″, *fig.* 2107 (to the right of K), is the whip or lever-end; Q″, its centre of motion (corresponding to the right arm and elbow of the weaver), which serves to throw the shuttle by means of the pecking-cord *p″*, attached at its other end to the drivers O, O.

On the axis of Q″, a kind of excentric or heart wheel is mounted, to whose concave part, the middle of the double band or strap *r*, being attached, receives impulsion; its two ends are attached to the heads of the bolts *r′*, which carry the stirrups *r″*, that may be adjusted at any suitable height, by set screws.

S (see the left-hand side of *fig.* 2107) is the moving shaft of wrought iron, resting on the two ends of the frame. S′ (see the right-hand side), is a toothed wheel, mounted exteriorly to the frame, upon the end of the shaft S. S″ (near S′), are two equal elbows in the same direction, and in the same plane, as the shaft S, opposite to the swords M, M, of the lay.

Z, is the loose, and Z′, the fast pulley, or riggers, which receive motion from the steam-shaft of the factory. Z′, a small fly-wheel, to regulate the movements of the main shaft of the loom.

T, is the shaft of the excentric tappets, cams, or wipers, which press the treddle-levers alternately up and down; on its right end is mounted T′, a toothed wheel in gear with the wheel S′, of one half its diameter. T′, is a cleft clamping collar, which serves to support the shaft T.

U, is a lever which turns round the bolt *u*, as well as the clink *h″*. U′, the click of traction, for turning round the cloth beam, jointed to the upper extremity of the lever U; its tooth *u′*, catches in the teeth of the ratchet-wheel H″. *u″* is a long slender rod, fixed to one of the swords of the lay M, serving to push the lower end of the lever U, when the lay retires towards the heddle-leaves.

X, is a wrought-iron shaft, extending from the one shuttle-box to the other, supported at its ends by the bearings, *x*, *x*.

Y, is a bearing, affixed exteriorly to the frame, against which the spring bar Z rests near its top, but is affixed to the frame at its bottom. The spring falls into a notch in the bar Y, and is thereby held at a distance from the upright A, as long as the band is upon the loose pulley *z′*; but when the spring bar is disengaged, it falls towards A, and carries the band upon the fast pulley *z*, so as to put the loom in gear with the steam-shaft of the factory.

Weaving, by this powerful machine, consists of four operations: 1, to shed the warp by means of the heddle-leaves, actuated by the tappet-wheels upon the axis Q′, the rods *k*, *k′*, the cross-bar E, and the eyes of the heddle-leaves I, I′; 2, to throw the shuttle (see *fig.* 2107), by means of the weft lever P″, the driver cord *p*, and the pecker *o*; 3, to drive home the weft by the batten N, N′; 4, to unwind the chain from the warp beam, and to draw it progressively forwards, and wind the finished web upon the cloth beam H, by the click and toothed wheel mechanism at the right-hand side of the frame.

See COTTON, FLAX, TEXTILE FABRICS, &c.

WEAVING BY ELECTRICITY. So long ago as 1852, M. Bonelli constructed an electric loom, which was exhibited at that time in Turin; but the first trial to which the machine was submitted gave but small hope to those who saw it that the inventor would succeed in his object. The public trial at Turin, in 1853, in the presence of manufacturers, was not so successful as to remove all doubts as to the merits of the novel apparatus. In the following year it was submitted to the judgment of the Academy of Sciences at Paris, who appointed a committee to examine it, but it is believed that no report was ever made. In 1855, a model of the loom had a place at the Universal Exhibition of Paris, but the lateness of its arrival there prevented any official report being made in reference to its merits. M. Bonelli afterwards devoted much time and attention in endeavouring to remedy its defects and to perfect its working, so as to render it capable of holding its place in the factory. This M. Bonelli believed he had at last accomplished, and he brought over to this country not merely a model, but a loom in complete working order, which he submitted to the judgment of manufacturers, as a machine, which, from its economy and efficiency, might be put in favourable comparison with the Jacquard loom.

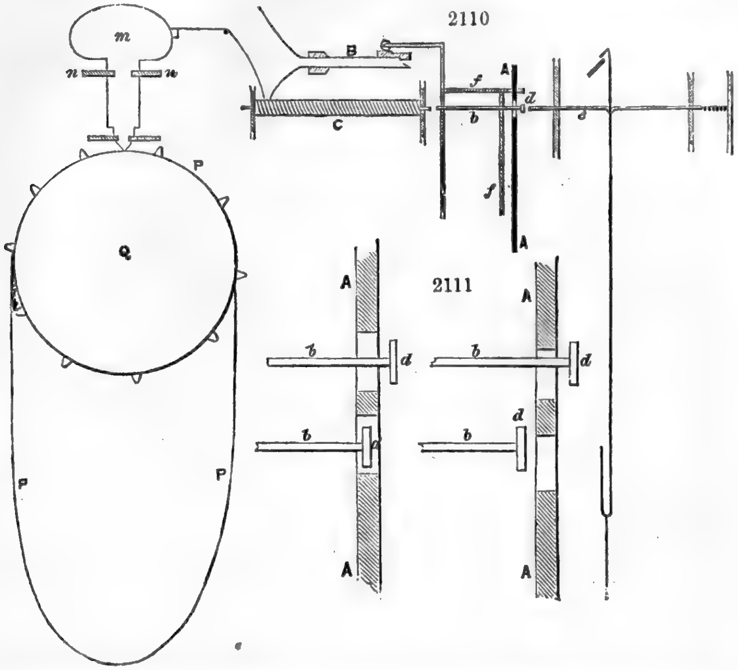
In the first place, it must be understood that the special object of M. Bonelli's machine was to do away with the necessity for the Jacquard cards used to produce the pattern at the present time, the source of delay and very considerable cost, more especially in patterns of any extent and variety of treatment. M. Bonelli used an endless band of paper, of suitable width, the surface of which is covered with tin-foil. On this metallised surface, the required pattern is drawn, or rather painted with a brush in black varnish, rendering the parts thus covered non-conducting to a current of electricity. This band of paper, bearing the pattern, being caused to pass under a series of thin metal teeth, each of which is in connection with a small electro-magnet, it will be readily conceived that as the band passes under these teeth, a current of electricity from a galvanic battery may be made to pass through such of the teeth as rest on the metallised or conducting portion of the band, and from such teeth, through the respective coils, surrounding small bars of soft iron, thus rendering them temporary magnets, while no current passes through those connected with the teeth resting on the varnished portions. Thus, at every shift of the band, each electro-magnet in connection with the teeth becomes active or remains inactive according to the varying portion of the pattern which happens to be in contact with the teeth. In a moveable frame opposite the ends of the electro-magnets, which, it should be stated, lie in a horizontal direction, are a series of small rods or pistons, as M. Bonelli termed them, the ends of which are respectively opposite to the ends of the electro-magnets. These pistons are capable of sliding horizontally in the frame, and pass through a plate attached to the front of it. When this frame is moved so that the ends of the pistons are brought into contact with the ends of the electro-magnets they are seized by such of them as are in an active state, and on moving the frame forward, those are retained while the others are carried back with it, and, by means of a simple mechanical arrangement, becomes fixed in their places ; thus there is in front of the frame a plate, with holes, which are only open where the pistons have been withdrawn, and this plate, as will be readily understood, acts the part of the Jacquard card, and is suitable for receiving the steel needles which govern the hooks of the Jacquard in connection with the warp threads as ordinarily used.

The ordinary Jacquard cards are shown in the following woodcut, *fig.* 2110.

Instead of this arrangement, which will be understood by reference to the article **Jacquard**, M. Bonelli, as we have said, instead of the cards prepares his design on metal foil, in a resinous ink, which serves to interrupt the current, and thus effect the object of the machine.

Figs. 2110 and 2111 explain generally the arrangements by which the process is effected.

A, *fig.* 2110, represents the plate pierced with holes, which plays the part of the card. Each of the small pistons or rods, *b*, forming the armatures of the electro-magnets *c*, have a small head, *d*, affixed to the end, exactly opposite the needles, *e*, of the Jacquard, and are capable of passing freely through the holes of the plate, A. At a given moment the plate is slightly lowered, which prevents the heads of the pistons passing, and the surface of the plate then represents a plain card. The pistons are supported on a frame, *f f*, which allows them to move horizontally in the direction of their length. At each stroke of the shuttle, the frame, carrying with it the plate A, has, by means of the treddle, a reciprocating motion backwards and forwards, and in its backward movement presents the end of the pistons to one of the poles of the electro-magnets, and, by means of certain special contrivances, contact with the magnets is secured. When the frame, *f f*, returns with the plate A towards the needles of the Jacquard, the electro-magnets, which become temporarily magnetised by the electric current, hold back the pistons, the heads of which pass through the plate A, and rest behind it. On the other hand, the electro-magnets which are not magnetised, owing to the course of the current being interrupted, permit the other pistons to be carried back, their heads remaining outside the plate and in front of it. At this moment, the plate, by means of an inclined plane beneath it, is lowered slightly, thus preventing the heads of the pistons passing through the holes, by the edges of which they are stopped, so as to push against the needles of the Jacquard; on the other hand, the heads of the pistons which have passed within and to the back of the plate, leave the corresponding holes of the plate free, and the needles of the Jacquard which are opposite to them are allowed to enter.


2110

2111

The electro-magnets are put into circuit in the following manner: One of the ends of the wire forming the coil of each of the magnets is joined to one common wire in connection with one of the poles of a galvanic battery. The other end of the coil-wire of each magnet is attached to a thin metallic plate, *m*, having a point at its lower extremity. All these thin metallic plates are placed side by side, with an insulating material between them, formed like the teeth of a comb, *n n*. At a given time, these thin plates rest with their lower extremities on the sheet bearing the design P, which, in the form of an endless band, is wrapped round and hangs upon the cylinder, Q, and according as the thin metal-plate rests on a metallised or on a non-conducting portion of the design, the corresponding electro-magnet is or is not magnetised, and its corresponding piston does not or does press against the needle of the Jacquard. The wire from the other pole of the battery of course communicates with the band bearing the design, by being attached to a piece of metal, which lies in constant contact with the metallic edge of the band. At B is a contact-breaker, which is put in motion by the movement of the frame. Besides this, by means of a mechanical arrangement connected with the treddle, which raises or depresses the griff frame, the band bearing the design is carried forward at each stroke, and the rapidity with which it is made to travel can readily be regulated, by means of gearing, at the will of the workman. By regulating the speed of the band, and by the use of thicker or thinner weft, an alteration in the character of the woven material may be made, whilst the same design is produced, though in a finer or coarser material.

Such are the arrangements by which the loom will produce a damask pattern, or one arising from the use of two colours, one in the warp, and the other in the weft. The method adopted by M. Bonelli for producing a pattern where several colours are required will now be explained.

The design is prepared on the metallised paper, so that the coloured parts are represented by the metallised portion of the band, but each separate colour is, by removing a very thin strip of the foil at the margin, insulated from its neighbouring colour. Then all the pieces of foil thus insulated, which represent one colour or shade, are connected with each other by means of small strips of tin-foil, which pierce through the paper and are fastened at the back, and are conducted to a strip of tin-foil which runs along the edge of the band, there being as many such strips of tin-foil as there are colours. Thus each special colour of the pattern, in all its parts, is connected by a conductor with its own separate strip of tin-foil, and by bringing the wire from the pole of the battery successively into contact with the several strips, a current of electricity may be made to pass in succession through the several parts of the design on the band representing the separate colours of the design. Thus, assuming four colours, 1, 2, 3, 4, there would be four strips of tin-foil running the length of the band, insulated from each other, each of which would be in connection with its own separate colour only. At any given moment, the thin plates of metal resting on the pattern would touch in a line which, as it passes over the width of the pattern, would run through all, or any one or more of the colours, but the electric current would pass only through those plates which rest on the one colour represented by the strip with which the pole of the battery at that instant was in contact.

The inventor claims the following as the results of his invention:—

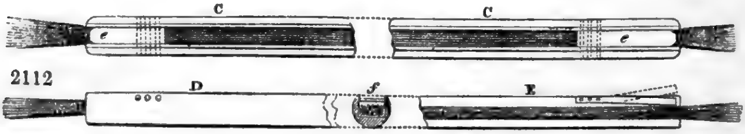
First.—The great facility with which, in a very short time, and with precision, reductions of the pattern may be obtained on the fabric by means of the varying velocity with which the pattern may be passed under the teeth.

Second.—That without changing the mounting of the loom or the pattern, fabrics thinner or thicker can be produced by changing the number of the weft, and making a corresponding change in the movement of the pattern.

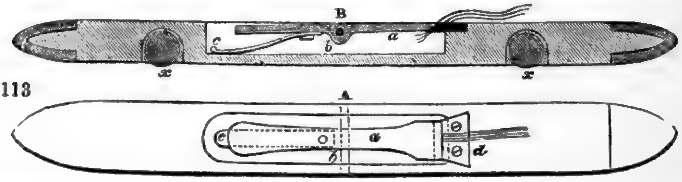
Third.—The loom and its mounting remaining unchanged, the design may be changed in a few minutes by the substitution of another metallised paper having a different pattern.

Fourth.—The power of getting rid of any part of the design if required, and of modifying the pattern.

WEAVING OF HAIR-CLOTH. In addition to the description of this art under Hair, a short notice is required of the best kind of shuttle for weaving hair. *Fig.* 2113 shows in plan A, and in longitudinal section B, a shuttle which differs from that of the common cloth-weaver only in not having a pirn enclosed in the body of the box-wood, but merely an iron trap *a*, which turns in the middle upon the pin *b*. This trap-piece is pressed up at the one end, by the action of the spring *c*, so as to bear with its other end upon the cleft of the iron plate *d*, which is intended to hold fast the ends of the hair-weft: *d* and *c* together are called 'the jaws' or 'mouth,' whence the popular name of this shuttle. The workman opens this jaw by the pressure of his thumb upon the spring end of the trap *a*, introduces with the other hand one or more hairs (according to the description of hair-cloth,) into the mouth, and removing his thumb, lets the hairs be seized by the force of the spring. The hairs having one end thus made fast are passed across the warp by the passage of the shuttle, which is received at the other end by the weaver's left hand. The friction rollers, *x*, *x*, are like those of fly-shuttles, but are used merely for convenience, as the shuttle cannot be thrown swiftly from side to side. The hand which receives the shuttle opens at the same time the trap, in order to insert another hair, after the preceding has been drawn through the warp on both sides and secured to the list. A child attends to count and stretch the hairs. This assistant may, however, be dispensed with by



2112



2113

means of the following implement, represented in *fig* 2112. C, C is the view of it from above, or the plan; D is a side view; E a longitudinal section, and *f* an oblique section across. The chief part consists in a wooden groove, or chamfered slip of wood, open above, and rounded on the sides. It is about 21 inches in length, about as long nearly as the web is broad, therefore a little shorter than the horse-hairs inserted in it, which project about an inch beyond it at each end. They are herein pressed down by elastic slips, *e*, of india-rubber, so that the others remain, when one or more are drawn out by the ends. The ends of the grooves are flat where the india-rubber spring exerts its pressure, as shown by the dotted line *f*. The spring is formed by cutting out a double piece from the curvature of the neck of a caoutchouc bottle or flask, fastening the one end of the piece by a wire staple in the groove of the shuttle, whereby the other end, which alone can yield, presses upon the inlaid hair. Wire staples like *f* (in the section E) are passed obliquely through two places of the groove or gutter, to prevent the hairs from springing up in the middle of the shuttle, which is suitably charged with them. The workman shoves the tool across the opened warp with the one hand, seizes with the other the requisite number of hairs by the projecting ends, and holds them fast while he draws the shuttle once more through the warp. The remaining hairs are retained in the groove by the springs, and only those for the single decussation remain in the web, to be secured to the list on either side. A weaver with this tool can turn out a length of cloth double of what he could do with the mouth-shuttle.

WEBSTERITE. A hydrous subsulphate of alumina, found at Newhaven and Brighton, in Sussex; at Halle; and in several French localities.

WEFT (*Trame*, Fr.; *Eintrag*, Ger.) is the name of the yarns or threads which run from selvage to selvage in a web.

WEIGHING MACHINE. See BALANCE.

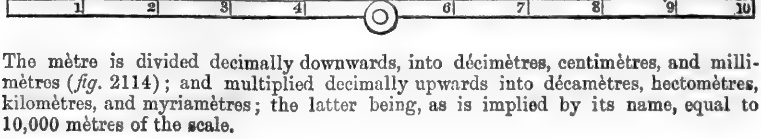
WEIGHTS and **MEASURES.** *Metrical and Imperial.* The metrical system originated with the government of Louis XV., who named a commission to pursue the investigations necessary to decide the principles upon which such a system could be carried out. An extensive series of observations were conducted during the reign of Louis XVI. Under his consent the Academy of Sciences decided that all the different weights, measures, and coinages should be established accessory to certain definite relations to the dimensions of the globe itself.

Delambre and Méchain ascertained the length of the earth's meridian in the portion between Dunkirk and Barcelona, and Arago and Biot that between Barcelona and Formentera. The length of the meridian from the Pole to the Equator, passing through Paris, was then divided into 10,000,000 parts, and one of these parts, called the *mètre*, became the basis of the new system.

Maupertuis had, in the year 1736, measured a portion of the arc of the meridian passing through the North Cape. His observations were therefore combined with the others by the commission. The distance from the Equator to the Pole, which is really 10,000,738, was fixed at 10,000,000. This standard is, therefore, the ten-millionth part of the quadrant of the terrestrial meridian; and from the measurements and calculations which were made at that period on the arc of the meridian which extended from Barcelona to Dunkirk, it was reckoned to be 39·371 inches of the English standard yard, which contained 36 inches. Thus the French mètre, which is longer than the English yard by $3\frac{1}{3}$ inches, or more accurately by $3\frac{10}{27}$ inches, is the standard of all the measures and weights of France. Its decimal multiples are successively denoted by the prefixes *deca, heca, kilo*, &c., which signify 10, 100, 1000, &c., times respectively; and its decimal submultiples or fractions successively by the prefixes *deci, centi, milli*, &c., which signify $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, &c., parts respectively. The mètre itself was made the unit of lineal measure and itinerary distances.

A bar of platinum was constructed representing the length of the mètre as accurately as possible; and this bar, or others directly or indirectly copied from it, is the standard unit of length throughout France, and in many other countries which have herein followed her example. It is equal to 39·371 English inches, and is about $\frac{1}{4}$ of an inch longer than a pendulum vibrating seconds at the level of the sea in London.

2114



The mètre is divided decimally downwards, into décimètres, centimètres, and millimètres (*fig.* 2114); and multiplied decimally upwards into décamètres, hectomètres, kilomètres, and myriamètres; the latter being, as is implied by its name, equal to 10,000 mètres of the scale.

A *décimètre*, as its name implies, is the tenth part of a mètre. In like manner a *centimètre* is the hundredth part, and a *millimètre* is the thousandth part, of a mètre.

A square formed upon a line of ten mètres is the unit of superficial or land measure; and a cube which has a *décimètre* (or one-tenth of a mètre) for its measuring line, is called a *litre*—the unit of capacity. Each of these is increased or diminished by multiples or submultiples of ten; but for the convenience of those who prefer halves and quarters to tenths, each may be, and often is, divided in this manner, though all arithmetical calculations are performed decimally. The fundamental unit of weight is the *kilogramme*, which is the weight of a litre of distilled water, at its greatest density, which is a little above the freezing-point. The thousandth part of a kilogramme is called a *gramme*.

To recapitulate:—

The multiples of the *mètre* are the *déca*mètre = 10 mètres.
" " *hecto*mètre = 100 mètres.
" " *kilo*mètre = 1000 mètres.
" " *myria*mètre = 10,000 mètres.

The submultiples of the mètre are the *déci*mètre = the 10th part of a mètre.
" " *centi*mètre = the 100th part of a mètre.
" " *milli*mètre = the 1000th part of a mètre.

The unit of surface is the *are*, which is the square of 10 mètres on a side, or 100 superficial mètres. The usual multiples and submultiples are the *hect*-are, a square of 100 mètres on a side, and the *centi*-are, the mètre superficial. These terms are employed in the sale of land, and in agricultural discussions.

The unit of weight is the *gramme*, which is the equivalent of a cube of distilled water, at the zero of the Centigrade scale (32° of Fahrenheit), measuring a centimètre every way. The multiples are:—

The *Décagramme* . . . . = 10 grammes.
" *Hectogramme* . . . . = 100 grammes.
" *Kilogramme* . . . . = 1000 grammes.

The submultiples are:—

The *Décigramme* . . . . = the 10th part of a gramme.
" *Centigramme* . . . . = the 100th part of a gramme.
&c. &c.

A thousand kilogrammes will form a cube measuring a mètre on every side, and it is made the legal *ton* for heavy weights.

The unit of capacity is the *litre*, which is the equivalent of a cube measuring one-tenth part of a mètre every way. The multiples are the *décalitre*, the *hectolitre*, the *kilolitre*, and the submultiples, the *décilitre*, the *centilitre*, &c. The *litre* is usually employed in expressing the quantities of liquids. A thousand litres of water are equal to a mètre cube every way, and one ton in weight. The *hectolitre* is used in expressing the measures of grain.

The following Tables, constructed by Mr. Warren De La Rue, and published in his 'Diary and Almanack,' are reproduced here by his obliging permission:—

French Measures of Length.

	In English inches	In English feet = 12 inches	In English yards = 3 feet	In English fathoms = 6 feet	In English miles = 1760 yards
Millimètre . . .	0·03937	0·003281	0·0010936	0·0005468	0·0000006
Centimètre . .	0·39371	0·032809	0·0109363	0·0054682	0·0000062
Décimètre . . .	3·93708	0·328090	0·1093633	0·0546816	0·0000621
Mètre	39·37079	3·280899	1·0936331	0·5468165	0·0606214
Décamètre . . .	393·70790	32·808992	10·9363310	5·4681655	0·0062138
Hectomètre . .	3937·07900	328·089920	109·3633100	54·6816550	0·0621382
Kilomètre . . .	39370·79000	3280·899200	1093·6331000	546·8165500	0·6213824
Myriamètre . .	393707·90000	32808·992000	10936·3310000	5468·1655000	6·2138244

1 inch = 2·539954 centimètres.
1 foot = 3·0472449 décimètres.
1 yard = 0·9143835 mètre.
1 mile = 1·6093149 kilomètre.

French Measures of Surface.

	In English sq. feet	In English sq. yards = 9 sq. feet	In English poles=272·25 sq. feet	In English roods=10890 sq. feet	In English acres=43560 sq. feet
Centiare or sq. mètre	10·764299	1·196033	0·0395383	0·0009885	0·0002471
Are or 100 sq. mètres	1076·422934	119·603326	3·9538290	0·0988467	0·0247114
Hectare or 10,000 sq. mètres . . .	107642·993418	11960·332602	395·3828959	9·8845724	2·4711431

1 square inch=6·4513669 square centimètres.
1 square foot =9·2899683 square décimètres.
1 square yard=0·83609715 square mètre or centiare.
1 acre =0·40467102 hectare.

French Measures of Capacity.

	In cubic inches	In cubic feet =1728 cubic inches	In pints =34·65923 cubic inches	In gallons =8 pints =277·27384 cubic inches	In bushels =8 gallons =2218·19075 cubic inches
Millilitre, or cubic centimètre . .	0·06103	0·000035	0·00176	0·0002201	0·0000275
Centilitre, or 10 cubic centimètres . .	0·61027	0·000353	0·01761	0·0022010	0·0002751
Décilitre, or 100 cubic centimètres . .	6·10271	0·003532	0·17608	0·0220097	0·0027512
Litre, or cubic décimètre . . .	61·02705	0·035317	1·76077	0·2200967	0·0275121
Décalitre, or centistère . . .	610·27052	0·353166	17·60773	2·2009668	0·2751208
Hectolitre, or décistère . . .	6102·70515	3·531658	176·07734	22·0096677	2·7512085
Kilolitre, or stère, or cubic mètre . .	61027·05152	35·316581	1760·77341	220·0966767	27·5120846
Myriolitre, or décastère . . .	610270·51519	353·165807	17607·73414	2200·9667675	275·1208459

1 cubic inch=16·386176 cubic centimètres. 1 cubic foot=28·315312 cubic décimètres.
1 gallon=4·543458 litres.

French Measures of Weight.

	In English grains	In troy ounces =480 grains	In avoirdupois lbs.=7000 grs.	In cwts.=112 lbs.=784000 grains	Tons=20 cwts. =15680000 grs.
Milligramme . .	0·01543	0·000032	0·0000022	0·0000000	0·0000000
Centigramme . .	0·15432	0·000322	0·0000220	0·0000002	0·0000000
Décigramme . .	1·54323	0·003215	0·0002205	0·0000020	0·0000001
Gramme . . .	15·43235	0·032151	0·0022046	0·0000197	0·0000010
Décagramme . .	154·32349	0·321507	0·0220462	0·0001968	0·0000098
Hectogramme . .	1543·23488	3·215073	0·2204621	0·0019684	0·0000984
Kilogramme . .	15432·34880	32·150727	2·2046213	0·0196841	0·0009842
Myriagramme . .	154323·48800	321·507267	22·0462126	0·1968412	0·0098421

1 grain=0·064799 gramme. 1 troy ounce=31·103496 gramme.
1 lb. avoirdupois=0·453593 kilogramme. 1 cwt.=50·802377 kilogrammes.

Troy Weight, so called from Troyes, a town in the province of Champagne in France, now in the department of Aube, where a celebrated fair was held, appears to have come into general use in England about the time of Henry IV. The first mention of the term *Avoir du pois* occurs in a charter of 31 Edward I. 'Pound' is derived from the Latin *pondus*; 'ounce,' from *uncia*, or twelfth part, being the $\frac{1}{12}$th part of a lb. Troy.

Al measures of capacity were first taken from Troy weight; and several laws were passed in the reign of Henry III., enacting that 8 lbs. troy of wheat, taken from the middle of the ear, and well dried, should make 1 gallon of wine measure; and 8 such gallons made a bushel.

Avoirdupois Weight was first made legal in the reign of Henry VII., and its particular use was to weigh provisions and coarse, heavy articles. Henry fixed the stone at 14 lbs., which has been confirmed by a recent Act of Parliament.

Agreeably to the Act of uniformity, which took effect 1st January, 1826, the term 'measure' may be distinguished into eight kinds: viz., length, surface, volume, specific gravity, capacity, space, time, and motion.

Troy Weight.

Marks		Ounces	Dwts.	Grains
dwt.	Pennyweight	...	...	24
oz.	Ounce	...	20	480
℔.	Pound	12	240	5760

Troy weight is used for money, precious metals, and jewels. Also in philosophical experiments, though the more convenient decimal divisions of the French gramme are almost universally preferred by scientific chemists of the present time.

Apothecaries' Weight.

Marks		Ounces	Drams	Scruples	Grains
℈	Scruple	...	...	...	20
ʒ	Dram	...	...	3	60
℥	Ounce	...	8	24	480
℔	Pound	12	96	288	5760

The ounce and pound are the same as in Troy weight, but differently subdivided. A grain is alike in all weights.

Avoirdupois Weight.

	Cwts.	Quarters	Pounds	Ounces	Drams
Ounce (437½ grains)	...	...	...	...	16
Pound (7000 grains)	...	...	...	16	256
Stone	...	...	14	224	3584
Quarter	...	...	28	448	7168
Hundred-weight	...	4	112	1792	28672
Ton	20	80	2240	35840	573440

This weight is used for all substances, except gold, silver, and precious stones. Drugs are sold by this weight, but medicines are compounded by Apothecaries' weight.

Measures of Length.—The imperial standard yard is divided into 3 feet, and each foot into 12 inches, and its length is fixed (see Act of Parl. 5 Geo. IV. c. 74) by reference to the length of the pendulum vibrating seconds in the latitude of London, in a vacuum at the level of the sea; the former being to the latter in the proportion of 36 imperial inches to 39·1393 imperial inches. The length of the seconds pendulum at Greenwich is 39·13929 inches; at Leith Fort (nearly the parallel of Glasgow), under the same circumstances, it is 39·1555 imperial inches; and at New York, 39·1017 imperial inches. The imperial standard yard may, however, be more distinctly defined as the distance between the points of oscillation and suspension of a pendulum vibrating in a mean solar day (in a vacuum at the level of the sea,) at London 90,088 times. The Scotch standard ell (the use of which is now abolished,) measured 37 imperial inches.

An inch, formerly divided into 3 barleycorns, is now the smallest lineal measure to which a name is given, but subdivisions are used for many purposes.

Cloth Measure.

	Quarters	Nails	Inches
Nail	...	...	2¼
Quarter	...	4	9
Yard	4	16	36
Ell	5	20	45
French ell	6	24	54

Long Measure.

Inches	Links	Feet	Yards	Pole or Perch	Chains	Furlongs	Mile
7·92	1	...	...	...	...	...	...
12	1·515	1	...	...	...	...	...
36	4·545	3	1	...	...	...	...
198	25	16·5	5·5	1	...	...	...
792	100	66	22	4	1	...	...
7920	1000	660	220	40	10	1	...
63360	8000	5280	1760	320	80	8	1

In Ireland the perch contains 7 yards, and the mile 2240.

Scotch and Irish linens, all sorts of woollen cloths, muslins, ribbons, cords, tapes, &c., are measured by the yard. Dutch linens, called Hollands, are bought by the Flemish ell, and sold by the English ell.

The yard in Cloth Measure is the same as in Long Measure, but differs in its divisions and subdivisions, as under:—

2¼ inches	make 1 nail .	. nl.	3 quarters	make 1 Flemish ell	Fl. ell.
4 nails	„ 1 quarter	. qr.	5 quarters	„ 1 English ell	Eng. ell.
4 quarters	„ 1 yard .	. yd.	6 quarters	„ 1 French ell .	Fr. ell.

Linear Measure.

	Furlongs	Chains	Poles	Yards	Feet	Inches
Foot	...	...	...	...	...	12
Yard	...	...	...	...	3	36
Pole or Rod . .	...	...	...	5½	16½	198
Chain of 100 links .	...	...	4	22	66	792
Furlong . . .	...	10	40	220	660	7920
Mile	8	80	320	1760	5280	63360

A League is 3 miles. A Hand (used in measuring horses), 4 inches. A Fathom, 2 yards, or 6 feet, or 72 inches.

A pendulum, which vibrates seconds of mean time in the latitude of London, at the level of the sea and in a vacuum, measures 39·1393 inches. It is by an accurate subdivision of the length of such a pendulum that an inch, the foundation of all other measures and weights, is obtained.

Land or Square Measure.

	Roods	Chains	Poles	Yards	Feet	Inches
Square foot . . .	...	...	...	...	...	144
Square yard . .	...	...	...	...	9	1296
Square pole or rod .	...	...	...	30¼	272¼	39204
Chain of 10,000 links .	...	...	16	484	4356	627264
Rood	...	2½	40	1210	10890	1568160
Acre	4	10	160	4840	43560	6272640

A square mile is 640 acres or 3,097,600 square yards.

Cubic or Solid Measure.

	Feet	Inches
Cubic foot	...	1728
Cubic yard	27	46656

A ton of shipping is 42 cubic feet. A barrel's bulk is 5 cubic feet.

Liquid Measure.

	Gallons	Quarts	Pints
Gill	...	...	¼
Quart	...	...	2
Gallon	...	4	8
Firkin or quarter barrel	9	36	72
Kilderkin or half barrel	18	72	144
Barrel	36	144	288
Hogshead of ale	54	216	432
Hogshead of wine	63	252	504
Puncheon	84	336	672
Butt of ale	108	432	864
Pipe of 2 hogsheads	126	504	1008
Tun or 2 pipes	252	1008	2016

Dry Measure.

	Quarters	Bushels	Pecks	Gallons
Peck	...	...	...	2
Bushel	...	...	4	8
Quarter	...	8	32	64
Load or wey	5	40	160	320

The imperial gallon is the legal standard measure both for dry goods and liquids. It contains 277·274 cubic inches of distilled water when the barometer stands at 30 inches and thermometer at 62° Fahr. Under the same conditions an imperial gallon of water weighs 10 avoirdupois pounds or 70,000 grains. A cubic inch of water weighs 252·458 grains. A cubic inch of air weighs 0·310 grain.

Time Table.

	Days	Hours	Minutes	Seconds
Minute	...	...	...	60
Hour	...	...	60	3600
Day	...	24	1440	86400
Week	7	168	10080	604800

A common year is 52 weeks 1 day, or 365 days. Every year which will divide by 4 without leaving any remainder is a leap year, and contains 366 days, except 1900, 2100, &c. A century contains 36,524 days.

Memoranda connected with various Irregular Weights and Measures.

A barrel of beer, 36 gallons.
„ ale, 32 „
A butt of sherry, 108 gallons, or 52 dozen bottles.
Hogshead of French wine, 43 to 46 gals.
Aum of hock, 30 gallons.
Pipe of madeira, 92 gallons.
„ port, 115 „ or 57¼ dozen bottles.
(Hogsheads one half, and quarter-casks one fourth part of that quantity.)
Pipe of Teneriffe, 100 gallons.
„ Lisbon, 117 „
„ Malaga, 105 „
Tun of wine, 252 gallons.
Hogshead of claret, 46 gallons.
Puncheon of brandy, 100 to 115 gallons.
Puncheon of rum, 90 to 100 gallons.
„ whisky, 120 „
A dicker of hides, 10 skins.
A last of hides, 20 dickers.
A dicker of gloves, 10 dozen pairs.
A box of raisins, 56 lbs.
Cask of rice, 7 to 8 cwts.
Chest of congou tea, 80 to 100 lbs.
Chest of hyson tea, 60 to 80 lbs.
Drum of figs, 6 to 14 lbs.
Pocket of hops, 1½ to 2 cwts.
A bag of hops, nearly 3½ cwts.
Firkin of butter, 56 lbs.
Load of hay or straw, 36 trusses.
Truss of hay, old, 56 lbs.
„ new, 60 lbs.
„ straw, 36 lbs.

Load of bricks, 500.
„ plain tiles, 1000.
Sack of flour, 280 lbs.
Tierce of sugar, 9 to 12 cwts.
„ coffee, 4 to 9 cwts.
Barrel of tar, 26¼ gallons.
Fodder of lead, 19½ cwts.
Gross, 144, or 12 dozen.
Quire of paper, 24 sheets.
Ream „ 480 sheets, or 20 quires.
Roll of parchment, 60 skins.
A weigh of cheese, 236 lbs.
5 quarters, a weigh or load.
A last of corn or rape-seed, 10 quarters or 80 bushels.
A last of potashes, cod-fish, white herrings, meal, pitch, and tar, 12 barrels.
A last of flax and feathers, 17 cwts.
A last of gunpowder, 24 barrels, or 2,400 lbs.
A last of wool, 4,568 lbs.
A tod of wool is 28 lbs.
A pack of ditto, 364 lbs.
48 solid feet of timber, a ton.
A stone of fish, 14 lbs., and of wool, 14 lbs. The same for horseman's weight, hay, iron, shot, &c.
A stone of glass, 5 lbs., and a seam of ditto, 24 stone.
A cade of red herrings, 500, and sprats, 1000.
A load of timber unhewed, 40 feet.
Flour, peck or stone, 14 lbs.
„ boll of 10 pecks or stones, 140 lbs.
„ sack of 2 bolls, 280 lbs.
„ barrel, 196 lbs.

Measures of Length.

A line is one-twelfth part of an inch.
A nail is 2¼ inches (used in measuring cloth).
A palm is 3 inches.
A hand is 4 inches (used in measuring the height of horses).
A span is 9 inches.
A cubit is 1½ foot.
A military pace is 2½ feet.
An itinerary pace is 5 feet.
A cable length is 120 fathoms, or 240 yards.
A league is 3 miles.
The knot, or nautical mile, 2,000 yards.
The old Scotch and Irish miles are 1⅛ and $1\frac{3}{11}$ English.

Coal Weights and Measures.

'From and after January 1, 1836, all coals, slack, culm, and cannel of every description shall be sold by weight and not measure, under a penalty of forty shillings.'
5 & 6 William IV.

The Chaldron. By this measure coal was formerly sold; it was 36 bushels or 12 sacks of coal.

The London imperial chaldron is about 25 cwts.
The Newcastle chaldron . . „ 53 cwts., or as about 11 to 21.

The relation of the chaldron to the ton in London is shown by the following results :—

		cwts.	qrs.	lbs.
1 chaldron of Russell's Hatton's Wallsend	weighed	25	0	8
„ Lambton's Wallsend	„	25	3	9
„ Russell's „	„	25	0	0
„ Northumberland	„	25	1	25
„ Tanfield Moor	„	26	0	17
„ Stewart's Wallsend	„	26	0	18
„ Killingworth	„	25	0	13

Mean, 25 cwts. 2 qrs. 4 lbs.

3 wains of 17½ cwts. }
6 carts of 8½ „ } make a Newcastle chaldron, which is only 52½.

The Keel is 8 chaldrons or 21 tons 7 cwts. (sometimes 4 cwts.), or 8 tubs = 21 tons 4 cwts.

The Bolls or *Boults.* In 1600, at a 'Courte of the Hostmen,' wains were ordered to be marked and measured. 'For time out of mind it hath been ordered that all coal wains did usually carry and bring 8 boults of coals to all staithes upon the river Tyne.'

Pecks	Boll	Chaldron	tons	cwts.	lbs.
8	1	...	0	4	23½
...	24	1	2	13	0
...	440	18¾ or 1 ten	48	11	74

The Ten. A local customary and arbitrary weight, being usually 440 coal bushels of 36 gallons Winchester, or 48 tons 11 cwts. 2 qrs. 17 lbs. 9 ozs. The Dean and Chapter of Durham, to avoid fractions, make the Ten 432 bushels, or 47 tons 14 cwts. 420 bolls, or sometimes 440 bolls make 1 Ten.

A Load of Coals.

At Newcastle is	1 ton of 20 cwts.
,, Morpeth	⅔ ton.
,, ,, (cart load) . .	15 to 16 cwts.
,, Lancashire	25 cwts.

A Waggon.

The Newcastle chaldron, 53 cwts. At Whitehaven, in 1826, 24 Carlisle bushels, weighing a little more than 2 tons.

About 25 years since the weight was 48 cwts. and it was increased to 50 cwts.

The Tub. In the Wear the best coal is put into tubs, these are waggons without wheels, containing each 53 cwts.

The Basket.

West Lancashire 6 cwts.
East ,, 3 ,, sometimes 4 cwts., according to the thickness of the 'mine.'

The Room. Coal-barges are divided into rooms, containing 180 bushels and 1 vat more, or 5 chaldrons and a vat.

The Vat, a quarter of a chaldron.
The Creel, sold in Ayrshire = 3 cwts.
An Acre of Stratum 1 foot thick is 31 tens.
An Acre of Coal = 1,510 tons.
A Fother of Coal = 17 cwts.

The Bushel.

Carlisle, 3 streaked Winchester weighing from 1 cwt. 2 qrs. 21 lbs. to 1 cwt. 3 qrs

Cornish .	. 94	lbs. (Lean's Engine Report).	
London .	. 82½	,,	
Standard .	. 86	,, avoirdupois	Distilled water
Imperial .	. 79 to 82	lbs. contains	2218·192 C. I.
Winchester	. ...	...	2150·42 C. I.

In Gutch's 'Literary and Scientific Register and Almanack' for 1872 the following statement of measures was given, which is so curious that it deserves preservation:—

'The Winchester bushel contains 2150·42 cubic inches, or 4 pecks; the *Waterside* measure contains 5 pecks. The old standard Scotch pint or sterling jug contains about 104 cubic inches, or 3 imperial pints; and the Scotch gallon contains 3 imperial gallons. The Scotch wheat firlot contains 24¼ Scotch pints; and the Scotch barley firlot, 31 Scotch pints. In Chester wheat is sold at 75 lbs. the bushel, or 9·23–28 gallons. In Cornwall (Launceston and Callington) the customary bushel is 16 gallons; at Helston, Falmouth, St. Austell, and Truro, the bushel consists of 24 gallons; at Redruth it is sold per 196 lbs. Cornish bushel; at St. Columb, 186 lbs., and at Bodmin, 62 lbs., per imperial bushel. In Devon a sack contains 40 gallons, a bag 16 gallons (in some parts 32 gallons); at Hereford wheat is sold sometimes by the bushel of 8 gallons, sometimes by the old bushel of 10 gallons, sometimes by weight, varying from 62 lbs. imperial, or 64 lbs. Winchester, to 80 lbs. old 10 gallons; in Norfolk, by the coomb of 4 bushels; in Northumberland (Alnwick, Morpeth, and Hexham markets), per new boll of 16 gallons; in Bedford and Wooller markets by the old boll of 48 gallons; in Salop the bushel is 75 lbs. net; York (North Riding), 63 lbs. per bushel; West Riding, at Wakefield corn exchange, per bushel of 60 lbs.; at the farmers' market, per the load of 3 bushels or 24 gallons measure, or load weighing 12 stone 12 lbs. (or 180 lbs.) to 14 stone (or 196 lbs.); at Leeds, Barnsley, Pontefract, Doncaster, Selby, Otley, Knaresborough, Ripon, Skipton, and Snaith, the same as at one or the other of Wakefield markets; Wales (Anglesea), at 63 lbs. per bushel; at Brecon, by the bushel of 8 gallons and the bushel of 10 gallons; Cardigan, 63 lbs.; Carmarthen, 64 lbs.; Flint, by the hobbet of 21 gallons, or 168 lbs.; Glamorgan (borough of Swansea), by the bushel or stack of 24 gallons, or by a measure called 'a peck,' containing 6 gallons. In the eastern part of the county there is also a bushel measure in use, called 'the Welsh bushel.' In Montgomery and Radnor the bushel is 10 gallons, or 80 lbs. weight. All local weights and measures are abolished, and a standard adopted that all grain, meal, flour, butter, and potatoes shall be sold by the Avoirdupois, by the score of 20 lbs., by the cwt. of 100 lbs., and by the ton of 2,000 lbs.; and that all hay, straw, turnips, and mangold-wurtzel shall be sold by the Avoirdupois, by the score of 20 lbs., by the cwt. of 100 lbs., and by the ton of 2,000 lbs.'

The *Ton* varies in a similarly unfortunate manner:—

The Statute ton	called short ton . .	20 cwts. of 112 lbs.	= 2240 lbs
„ Staffordshire ton	„ long ton . .	20 „ 120 „	= 2400 „
„ „ „	„ boat ton . .	24 „ 120 „	= 2880 „
„ South Wales „	. . . .	from 2400 „	to 2618 „
„ Ayrshire „	. . . .	„ 2464 „	to 2520 „

WELD, or *Dyer's Weed* (*Gande*, Fr.; *Wan*, Ger.) A biennial plant, native of Britain, Italy, and various parts of Europe; the *Reseda luteola* of botanists. Weld is preferred to all other substances in giving the lively green-lemon yellow to silk. Although the quercitron bark has almost superseded it in calico-printing, weld is still largely used in dyeing silk a golden yellow, and in paper-staining.

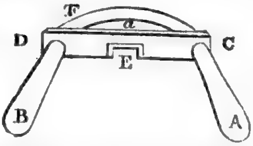
WELDING (*Souder*, Fr.; *Schweissen*, Ger.) is the property which pieces of wrought iron possess when heated to whiteness of uniting intimately under the hammer without any appearance of junction. See Iron.

WELLS, ARTESIAN. See Artesian Wells.

WHALEBONE (*Baleine*, Fr.; *Fischbeine*, Ger.) is the name of the horny laminæ, consisting of fibres laid lengthways, found in the mouth of the whale, which, by the fringes upon their edges, enable the animal to allow the water to flow out, as through rows of teeth (which are absent), from between its capacious jaws, but to catch and detain the minute creatures upon which it feeds. The fibres of whalebone have little lateral cohesion, as they are not transversely decussated, and may, therefore, be readily detached in the form of long filaments or bristles. The *blades*, or scythe-shaped plates, are externally compact, smooth, and susceptible of a good polish. They are connected, in a parallel series, by what is called the *gum* of the animal, and are arranged along each side of its mouth, to the number of about 300. The length of the longest *blade*, which is usually found near the middle of the series, is the gauge adopted by the fishermen to designate the size of the fish. The greatest length hitherto known has been 15 feet, but it rarely exceeds 12 or 13. The breadth, at the root end, is from 10 to 12 inches; and the average thickness, from four to five tenths of an inch. The series, viewed altogether in the mouth of the whale, resemble, in general form, the roof of a house. They are cleansed and softened before cutting, by boiling for 2 hours in a long copper.

Whalebone, as brought from Greenland, is commonly divided into portable junks or pieces, comprising ten or twelve blades in each; but it is occasionally subdivided into separate blades, the gum and the hairy fringes having been removed by the sailors during the voyage. The price of whalebone fluctuates from 50*l.* to 150*l.* per ton. The blade is cut into parallel prismatic slips, as follows:—It is clamped horizontally, with its edge up and down, in the large wooden vice of a carpenter's bench, and is then planed by the following tool, *fig.* 2115. A, B, are its two handles; C, D, is an iron plate, with a guide-notch E; F, is a semicircular knife, screwed firmly at each end to the ends of the iron plate C D, having its cutting edge adjusted in a plane, so much lower than the bottom of the notch E, as the thickness of the whalebone slip is intended to be for different thicknesses: the knife may be set by the screws at different levels, but always in a plane parallel to the lower guide surface of the plate C D. The workman, taking hold of the handles A, B, applies the notch of the tool at the end of the whalebone blade furthest from him, and with his two hands pulls it steadily along, so as to shave off a slice in the direction of the fibres; being careful to cut none of them across. These prismatic slips are then dried, and planed level upon their other two surfaces. The fibrous matter detached in this operation, is used, instead of hair, for stuffing mattresses.

2115



From its flexibility, strength, elasticity, and lightness, whalebone is employed for many purposes; for ribs to umbrellas or parasols; for stiffening stays; for the framework of hats, &c. When heated by steam- or a sand-bath, it softens, and may be bent or moulded, like horn, into various shapes, which it retains if cooled under compression. In this way, snuff-boxes, and knobs of walking-sticks, may be made from the thicker parts of the blade. The surface is polished at first with ground pumice-stone, felt, and water; and finished with dry quicklime spontaneously slaked, and sifted. Whalefins *Imported* in 1873—177 tons; valued at 64,618*l.* *Exported* in 1873—960 cwts.; valued at 18,710*l.*

WHALE OIL. See Oils.

WHARPE. See Trent Sand.

WHEAT. *Triticum vulgare*, Linn.; (*Froment*, Fr.; *Waizen*, Ger.) See Bread, Gluten, and Starch.

Wheat-Flour; *To detect Adulteration of.* Potato-starch is insoluble in cold water, unless it be triturated in thin portions in a mortar. If pure wheat-flour be thus triturated, it affords no trace of starch to iodine, as the former does, because the particles of wheat-starch are very minute, and are sheathed in gluten.

Bean-flour digested with water at a heat of 68° Fahr., and triturated, affords on filtration a liquid which becomes milky on the addition of a little acetic acid, by its reaction on the legumine present in the beans.

British Wheat returned as sold in various (150) *Market Towns of England and Wales in each month.*

	1867	1868	1869	1870	1871	1872	1873
	qrs.	qrs.	qrs.	qrs.	qrs.	qrs.	qrs.
January .	221,792	193,080	312,654	241,043	267,828	194,721	166,472
February .	203,902	259,963	254,916	231,919	309,377	193,911	202,979
March . .	280,880	176,768	217,452	259,539	298,965	245,614	238,127
April . .	205,233	173,122	204,521	308,798	371,536	191,523	159,269
May . .	221,069	193,994	249,080	280,739	222,005	231,783	277,881
June . .	197,017	97,184	213,005	230,572	191,126	268,628	167,467
July . .	109.831	106,814	204,293	217,370	158,780	109,545	101,103
August .	128,249	260,269	172,221	201,789	123,891	168,955	131,180
September .	239,727	358,663	220,167	351,231	371,592	253,592	232,664
October .	349,789	350,377	308,310	424,616	367,673	264,936	265,123
November .	337,170	267,345	218,513	298,408	269,354	248,832	264,925
December .	230,014	243,329	195,974	352,631	322,758	210,068	234,753
Total .	2,742,673	2,679,908	2,816,106	3,398,655	3,274,885	2,582,106	2,441,943

WHEEL CARRIAGES. This article is omitted from this edition to make room for articles more directly connected with the subjects legitimately belonging to it.

WHEEL ORE. See Bournonite.

WHETSLATE is a massive mineral of a greenish-grey colour; feebly glimmering; fracture slaty or splintery; fragments tabular; translucent on the edges; feels rather greasy; and has a spec. grav. of 2·722. It occurs in beds, in primitive and transition slates. Very fine varieties of whetslate are brought from Turkey, called *honestones*, which are in much esteem for sharpening steel instruments. See Hones.

WHEY (*Petit lait*, Fr.; *Molken*, Ger.) is the greyish-green liquor which exudes from the curd of milk. Scheele states, that when a pound of milk is mixed with a spoonful of proof spirit, and allowed to become sour, the whey filtered off, at the end of a month or a little more, is a good vinegar, devoid of lactic acid.

WHISKY. A spirit obtained by distillation from corn, sugar, or molasses, though generally from the former. It is extensively manufactured and used in Scotland and in Ireland. See Usquebaugh.

WHITE LEAD, *Carbonate of lead*, or *Ceruse.* (*Blanc de plomb*, Fr.; *Bleiweiss*, Ger.) This is the principal preparation of lead in general use for painting wood and the plaster walls of apartments white. It mixes well with oil, without having its bright colour impaired, spreads easily under the brush, and gives a uniform coat to wood, stone, metal, &c. It is employed either alone, or with other pigments, to serve as their basis, and to give them body. This article has been long manufactured with much success at Klagenfurth in Carinthia, and its mode of preparation has been described with precision by Marcel des Serres. The great white-lead establishments at Krems, whence, though incorrectly, the term *white of Kremnitz* became current, on the Continent, have been abandoned.

In Germany the manufacture of white lead is conducted as follows:—

The lead mostly comes from Bleiberg; it is very pure, and particularly free from contamination with iron, a point essential to the beauty of its factitious carbonate. It is melted in ordinary pots of cast iron, and cast into sheets of various thickness, according to the pleasure of the manufacturer. These sheets are made by pouring the melted lead upon an iron plate placed over the boiler; and whenever the surface of the metal begins to consolidate, the plate is slightly sloped to one side, so as to run off the still liquid metal, and leave a lead sheet of a desired thickness. It is then lifted off like a sheet of paper; and as the iron plate is cooled in water, several hundredweight of lead can be readily cast in a day. In certain white-lead works these sheets are one twenty-fourth of an inch thick; in others half that thickness; in some, one of these sheets takes up the whole width of the conversion-box; in others, four sheets are employed. It is of consequence not to smooth down the faces of the leaden sheets; because a rough surface presents more points of contact, and is more readily attacked by acid vapours than a polished one.

These plates are now placed so as to expose an extensive surface to the acid fumes, by folding each other over a square slip of wood. Being suspended by their middle, like a sheet of paper, they are arranged in wooden boxes, from 4½ to 5 feet long, 12 to 14 inches broad, and from 9 to 11 inches deep. The boxes are very substantially constructed; their joints being mortised, and whatever nails are used, being carefully covered. Their bottom is made tight with a coat of pitch about an inch thick. The mouths of the boxes are luted over with paper in the works where fermenting horse-dung is employed as the means of procuring heat, to prevent the sulphuretted and phosphuretted hydrogen from injuring the purity of the white lead. In Carinthia it was formerly the practice, as also in Holland, to form the lead sheets into spiral rolls, and to place them so coiled up in the chests; but this plan is not to be recommended, because these rolls present obviously less surface to the action of the vapours, are apt to fall down into the liquid at the bottom, and thus to impair the whiteness of the lead. The lower edges of the sheets are suspended about two inches and a half from the bottom of the box; and they must not touch either one another or its sides, for fear of obstructing the vapours in the first case, or of injuring the colour in the second. Before introducing the lead, a peculiar acid liquor is put into the box, which differs in different works. In some, the proportions are four quarts of vinegar, with four quarts of wine-lees; and in others a mixture is made of 20 pounds of wine-lees, with 8½ pounds of vinegar, and a pound of carbonate of potash. It is evident that in the manufactories where no carbonate of potash is employed in the mixture, and no dung for heating the boxes, it is not necessary to lute them.

The mixture being poured into the boxes, and the sheets of lead suspended within them, they are carried into a stove-room, to receive the requisite heat for raising round the lead the corrosive vapours, and thus converting it into carbonate. This apartment is heated generally by stoves, is about 9 feet high, 30 feet long, and 24 feet wide, or of such a size as to receive about 90 boxes. It has only one door.

The heat should never be raised above 86° Fahr.; and it is usually kept up for 15 days, in which time the operation is, for the most part, completed. If the heat be too high, and the vapours too copious, the carbonic acid in a great measure escapes, and the metallic lead, less acted upon, affords a much smaller product.

When the process is well managed, as much carbonate of lead is obtained as there was employed of metal; or, for 300 pounds of lead, 300 of ceruse are procured, besides a certain quantity of metal after the crusts are removed, which is returned to the melting-pot. The mixture introduced into the boxes serves only once; and if carbonate of potash has been used, the residuary matter is sold to the hatters.

When the preceding operation is supposed to be complete, the sheets, being removed from the boxes, are found to have grown a quarter of an inch thick, though previously not above a twelfth of that thickness. A few crystals of acetate of lead are sometimes observed on their edges. The plates are now shaken smartly, to cause the crust of carbonate of lead formed on their surfaces to fall off. This carbonate is put into large cisterns, and washed very clean. The cistern is of wood, most commonly of a square shape, and divided into from seven to nine compartments. These are of equal capacity, but unequal height, so that the liquid may be made to overflow from one to the other. Thereby, if the first chest is too full, it decants its excess into the second, and so on in succession.

The water poured into the first chest passes successively into the others, a slight agitation being meanwhile kept up, and there deposits the white lead diffused in it proportionally, so that the deposit of the last compartment is the lightest and finest. After this washing, the white lead receives another in large vats, where it is always kept under water. It is lastly lifted out, in the state of a liquid paste, with wooden spoons, and laid on drying-tables to prepare it for the market.

The white lead of the last compartment is of the first quality, and is called on the Continent 'silver white.' It is employed in fine painting.

When white lead is mixed in equal quantities with ground sulphate of baryta, it is known in France and Germany by the name of 'Venice white.' Another quality, adulterated with double its weight of sulphate of baryta, is styled 'Hamburgh white;' and a fourth, having three parts of sulphate to one of white lead, gets the name of 'Dutch white.' When the sulphate of baryta is very white, like that of the Tyrol, these mixtures are reckoned preferable for certain kinds of painting, as the barytes communicates opacity to the colour, and protects the lead from being speedily darkened by sulphurous smoke or vapours.

The high reputation of the white lead of Krems was by no means due to the barytes, for the first and whitest quality was mere carbonate of lead. The freedom from silver of the lead of Villach, a very rare circumstance, is one cause of the superiority of its carbonate; as well as the skilful and laborious manner in which it is washed, and separated from any adhering particle of metal or sulphide.

In England, lead is converted into carbonate in the following way:—The metal is cast into the form of a network grating, in moulds about 20 inches long, and 8 or 9 broad. Several rows of these are placed over cylindrical glazed earthen pots, about 6 or 7 inches in diameter, containing some wood-vinegar, which are then covered with planks and spent tan; above these pots another range is piled, and so in succession, to a convenient height. The whole are imbedded in spent bark from the tan-pit, brought into a fermenting state by being mixed with some bark used in a previous process. The pots are left undisturbed under the influence of a fermenting temperature for 8 or 9 weeks. In the course of this time the lead gratings become, generally speaking, converted throughout into a solid carbonate, which when removed, is levigated in a proper mill, and elutriated with abundance of pure water. The plan of inserting coils of sheet lead into earthenware pipkins containing vinegar, and imbedding the pile of pipkins in fermenting horsedung and litter, has now ceased to be used; because the coil is not uniformly acted on by the acid vapours, and the sulphuretted hydrogen evolved from the dung is apt to darken the white lead.

In the above processes, the conversion of lead into carbonate seems to be effected by keeping the metal immersed in a warm humid atmosphere, loaded with carbonic and acetic acids.

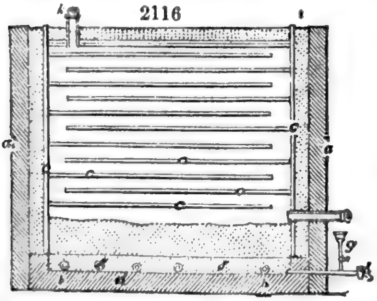
Another process has been practised to a considerable extent in France, though it does not afford a white lead equal in body and opacity to the products of the preceding operations. M. Thénard first established the principle, and MM. Brechoz and Lesseur contrived the arrangements of this method, which was subsequently executed on a great scale by MM. Roard and Brechoz.

A subacetate of lead is formed by digesting a cold solution of uncrystallised acetate, over litharge, with frequent agitation. It is said that 65 pounds of purified pyroligneous acid, of specific gravity 1·056, require, for making a neutral acetate, 58 pounds of litharge; and hence, to form the subacetate, three times that quantity of base, or 174 pounds, must be used. The compound is diluted with water as soon as it is formed, and being decanted off quite limpid, is exposed to a current of carbonic acid gas, which, uniting with the two extra proportions of oxide of lead in the subacetate, precipitates them in the form of a white carbonate, while the liquid becomes a faintly acidulous acetate. The carbonic acid may be extricated from chalk, or other compounds, or generated by combustion of charcoal, as at Clichy; but in the latter case it must be transmitted through a solution of acetate of lead before being admitted into the subacetate, to deprive it of any particles of sulphuretted hydrogen. When the precipitation of the carbonate of lead is completed and well settled down, the supernatant acetate is decanted off, and made to act on another dose of litharge. The deposit being first rinsed with a little water, this washing is added to the acetate: after which the white lead is thoroughly elutriated. This repetition of the process may be indefinitely made; but there is always a small loss of acetate, which must be repaired, either directly or by adding some vinegar.

It is customary on the Continent to mould the white lead into conical loaves before sending it into the market. This is done by stuffing well-drained white lead into unglazed earthen pots, of the requisite size and shape, and drying it to a solid mass by exposing these pots in stove-rooms. The moulds being now inverted on tables, discharge their contents, which then receive a final desiccation; and are afterwards put up in pale-blue paper, to set off the white colour by contrast.

It has been supposed that the differences observed between the ceruse of Clichy and the common kinds, depend on the greater compactness of the particles of the latter, produced by their slower aggregation; as also, according to M. Robiquet, on the former containing considerably less carbonic acid.

2116



Mr. Ham proposed, in a patent dated June 1826, to produce white lead with the aid of the following apparatus. *a*, *a*, *fig.* 2116, are the side-walls of a stove-room constructed of bricks; *b* is the floor of bricks laid in Roman cement; *c*, *c*, are the side-plates, between which and the walls a quantity of refuse tanners' bark, or other suitable vegetable-matter, is to be introduced. The same material is to be put also into the lower part at *d* (upon a false bottom or grating?). The tan should rise to a considerable height, and have a series of strips of sheet lead, *e*, *e*, *e*, placed upon it, which are kept apart by blocks or some other convenient means, with a space open at one end of the plates, for the passage of the vapours; but above the upper plates, boards are placed, and covered with tan, to confine them there. In the lower part of the chamber, coils of steam-pipes, *f*, *f*, are laid in different directions to distribute heat; *g* is a funnel-pipe, to conduct vinegar into the lower part of the vessel; and *h* is a cock to draw it off, when the operation is suspended. The acid vapours raised by the heat pass up through the spent bark, and on coming into contact with the sheets of lead, corrode them. The quantity of acid liquor should not be in excess; a point to be ascertained by means of the small tube *i*, at top, which is intended for testing it by the tongue. *k* is a tube for inserting a thermometer, to watch the temperature, which should not exceed 170° Fahr. We are not aware what success attended this patented arrangement.

A factory was many years since erected at West Bromwich, near Birmingham, to work a patent obtained by Messrs. Gossage and Benson, for making white lead by mixing a small quantity of acetate of lead in solution with slightly-damped litharge, contained in a long stone trough, and passing over the surface of the trough currents of hot carbonic acid, while its contents were powerfully stirred up by a travelling-wheel mechanism. The product was afterwards ground and elutriated, as usual. The carbonic acid gas was produced from the combustion of coke. This factory has long been abandoned.

Messrs. Button and Dyer obtained a patent for making white lead by transmitting a current of purified carbonic acid gas, from the combustion of coke, through a mixture of litharge and nitrate of lead, diffused and dissolved in water, which was kept in constant agitation and ebullition by steam introduced through a perforated coil of pipes at the bottom of the tub. The carbonate of lead was formed here upon the principle of Thénard's process upon the subacetate; for the nitrate of lead formed with the litharge a subnitrate, which was forthwith transformed into carbonate and neutral nitrate, by the agency of the carbonic acid gas. It is known that all sorts of white lead produced by precipitation from a liquid, are in a semi-crystalline condition; appear, therefore, semi-transparent when viewed in the microscope; and do not cover so well as white lead made by the process of vinegar and tan, in which the lead has remained always solid during its transition from the blue to the white state; and hence consists of opaque particles.

A patent was obtained in December 1833, by John Baptiste Constantine Torassa, and others, for making white lead by agitating the granulated metal or shot, in trays or barrels, along with water, and exposing the mixture of lead-dust and water to the air, to be oxidised and carbonated. The whole of these projects for preparing white lead are inferior in economy and quality of produce to the old Dutch process, which may be so arranged as to convert sheets of blue lead thoroughly into the best white lead, within the space of ten weeks, at less expense of labour than by any other plan.

The composition of the different varieties of white lead has been carefully examined by J. Arthur Phillips.[1] The result of this investigation shows that those specimens, which are obtained by precipitation from solutions of the nitrate by means of an alkaline carbonate, contain very variable quantities of oxide of lead, whilst in white lead prepared by the ordinary Dutch process, the relations existing between the amounts of carbonate and oxide, although definite, are usually very simple. The most usual composition of the white lead of commerce is represented by the formula $2(PbO.CO^2) + PbO.HO$ ($\mathbf{2PbCO^3.PbH^2O^2}$), although specimens represented by the formulæ $3(PbO.CO^2) + PbO.HO$ ($\mathbf{3PbCO^3.PbH^2O^2}$), and $5(PbO.CO^2) + PbO.HO$ ($\mathbf{5PbCO^3.PbH^2O^2}$) are also occasionally met with.

On examining the ordinary corroded leads in a finely-divided state, by the aid of a powerful microscope, no traces of a crystalline structure will be perceived, but when precipitated specimens are subjected to a power of 300 diameters, distinct hexagonal plates become visible. These vary from $\frac{1}{8000}$th to $\frac{1}{10000}$th of an inch in diameter, and appear slightly yellow by transmitted light.

Mr. Thomas Richardson, of Newcastle, obtained a patent in December 1839, for a preparation of sulphate of lead, applicable to some of the purposes to which the carbonate is applied. His plan is to put 56 lbs. of flake litharge into a tub, to mix it with 1 lb. of acetic acid (and water) of spec. grav. 1·046, and to agitate the mixture till the oxide of lead becomes an acetate. But whenever this change is partially effected, he pours into the tub, through a pipe, sulphuric acid of spec. grav. 1·5975, at the rate of about 1 lb. per minute, until a sufficient quantity of sulphuric acid has been added to convert all the lead into a sulphate; being about 20 parts of acid to

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[1] Journal of the Chemical Society, p. 145.

112 of the litharge. The sulphate is afterwards washed and dried in stoves for the market, but is very inferior to ordinary white lead.

Mr. Leigh, surgeon in Manchester, prepared his patent white lead by precipitating a carbonate from a solution of the chloride of the metal by means of carbonate of ammonia. On this process, in a commercial point of view, no remarks need be made.

A patent was granted to Mr. Hugh Lee Pattinson, in September 1841, for improvements in the manufacture of white lead, &c. This invention consists in dissolving carbonate of magnesia in water impregnated with carbonic acid gas, by acting upon magnesian limestone, or other earthy substances containing magnesia in a soluble form, or upon rough hydrate of magnesia in the mode hereafter described, and in applying this solution to the manufacture of magnesia and its salts, and the precipitation of carbonate of lead from any of the soluble salts of lead, but particularly the chloride of lead; in which latter case the carbonate of lead so precipitated is triturated with a solution of caustic potash or soda, by which a small quantity of chloride of lead contained in it is converted into hydrated oxide of lead, and the whole rendered similar in composition to the best white lead of commerce. The manner in which these improvements are carried into effect is thus described by the patentee:—

'I take magnesian limestone, which is well known to be a mixture of carbonate of lime and carbonate of magnesia in proportions varying at different localities; and on this account I am careful to procure it from places where the stone is rich in magnesia. This I reduce to powder, and sift it through a sieve of forty or fifty apertures to the linear inch. I then heat it red-hot, in an iron retort or reverberatory furnace, for two or three hours, when the carbonic acid being expelled from the carbonate of magnesia, but not from the carbonate of lime, I withdraw the whole from the retort or furnace, and suffer it to cool. The magnesia contained in the limestone is now soluble in water impregnated with carbonic acid gas, and to dissolve it I proceed as follows:—I am provided with an iron cylinder lined with lead, which may be of any convenient size, say 4 feet long by 2½ feet in diameter; it is furnished with a safety-valve and an agitator, which latter may be an axis in the centre of the cylinder, with arms reaching nearly to the circumference, all made of iron and covered with lead. The cylinder is placed horizontally, and one extremity of this axis is supported within it by a proper carriage, the other extremity being prolonged and passing through a stuffing-box at the other end of the cylinder, so that the agitator may be turned round by applying manual or other power to its projecting end. A pipe, leading from a force-pump, is connected with the under side of the cylinder, through which carbonic acid gas may be forced from a gasometer in communication with the pump, and a mercurial gauge is attached, to show at all times the amount of pressure within the cylinder, independently of the safety-valve. Into a cylinder of the size given I introduce from 100 to 120 lbs. of the calcined limestone with a quantity of pure water, nearly filling the cylinder; I then pump in carbonic acid gas, constantly turning the agitator, and forcing in more and more gas, till absorption ceases under a pressure of five atmospheres. I suffer it to stand in this condition three or four hours, and then run off the contents of the cylinder into a cistern, and allow it to settle. The clear liquor is now a solution of carbonate of magnesia in water impregnated with carbonic acid gas, or, as I shall hereafter call it, a solution of bicarbonate of magnesia, having a spec. grav. of about 1·028, and containing about 1,600 grains of carbonate of magnesia to the imperial gallon.

'I consider it the best mode of obtaining a solution of bicarbonate of magnesia from magnesian limestone, to operate upon the limestone after being calcined at a red heat in the way described; but the process may be varied by using in the cylinder the mixed hydrates of lime and magnesia, obtained by completely burning magnesian limestone in a kiln, as commonly practised, and slaking it with water in the usual manner: or, to lessen the expenditure of carbonic gas, the mixed hydrates may be exposed to the air a few weeks till the lime has become less caustic by the absorption of carbonic acid from the atmosphere. Or the mixed hydrates may be treated with water, as practised by some manufacturers of Epsom salts, till the lime is wholly or principally removed; after which the residual rough hydrate of magnesia may be acted upon in the cylinder, as described; or hydrate of magnesia may be prepared for solution in the cylinder, by dissolving magnesian limestone in hydrochloric acid, and treating the solution, or a solution of chloride of magnesium, obtained from sea-water by salt-makers in the form of bittern, with its equivalent quantity of hydrate of lime, or of the mixed hydrates of lime and magnesia, obtained by completely burning magnesian limestone, slaking it as above. When I use this solution of bicarbonate of magnesia for the purpose of preparing magnesia and its salts, I evaporate it to dryness, by which a pure carbonate of magnesia is at once obtained, without the necessity of using a carbonated alkali, as in the whole process; and from this I prepare pure magnesia by calcination in the usual manner; or, instead of boiling to dryness, I merely heat the solution for some time to the boiling point, by which the excess of carbonic acid is partly driven off, and pure carbonate of magnesia is precipitated, which may then be collected, and dried in the same way as if precipitated by a carbonated alkali. If I require sulphate of magnesia, I neutralise the solution of bicarbonate of magnesia with sulphuric acid, boil down, and crystallise; or I mix the solution with its equivalent quantity of sulphate of iron, dissolved in water, heated to the boiling point, and then suffer the precipitated carbonate of iron to subside; after which I decant the clear solution of sulphate of magnesia, boil down, and crystallise as before. When using this solution of bicarbonate of magnesia for the purpose of preparing carbonate of lead, I make a saturated solution of chloride of lead in water, which at a temperature of 50° or 60° Fahr., has a specific gravity of about 1·008, and consists of 1 part of chloride of lead dissolved in 126 parts of water. I then mix the two solutions together, when carbonate of lead is immediately precipitated; but in this operation I find it necessary to use certain precautions, otherwise a considerable quantity of chloride of lead is carried down along with the carbonate. These precautions are, first, to use an excess of the solution of magnesia; and secondly, to mix the two solutions together as rapidly as possible. As to the first, when using a magnesian solution containing 1,600 grs. of carbonate of magnesia, per imperial gallon, with a solution of chloride of lead saturated at 55° or 60° Fahr., 1 measure of the former to 8½ of the latter is a proper proportion; in which case there is an excess of carbonate of magnesia employed, amounting to about an eighth of the total quantity contained in the solution. When either one or both the solutions vary in strength, the proportions in which they are to be mixed must be determined by preliminary trials. It is not, however, necessary to be very exact, provided there is always an excess of carbonate of magnesia amounting to from one-eighth to one-twelfth of the total quantity employed. If the excess is greater than one-eighth, no injury will result, except the unnecessary expenditure of the magnesian solution. As to the second precaution, of mixing the two solutions rapidly together, it may be accomplished variously; but I have found it a good method to run them in two streams, properly regulated in quantity, into a small cistern, in which they are to be rapidly blended together by brisk stirring, before passing out, through a hole in the bottom, to a large cistern or tank, where the precipitate finally settles. The precipitate thus obtained is to be collected, washed and dried in the usual manner. It is a carbonate of lead, very nearly pure, and suitable for most purposes; but it always contains a small portion of chloride of lead, seldom less than from 1 to 2 per cent., the presence of which, even in so small a quantity, is somewhat injurious to the colour and body of the white lead. I decompose this chloride, and convert it into a hydrated oxide of lead by grinding the dry precipitate with a solution of caustic alkali, in a mill similar to the ordinary mill used in grinding white lead with oil, adding just so much of the lye as may be required to convert the precipitate into a soft paste. I allow this paste to lie a few days, after which, the chloride of lead being entirely, or almost entirely, decomposed, I wash out the alkaline chloride formed by the reaction, and obtain a white lead, similar in composition to the best white lead of commerce. I prepare the caustic alkaline lye by boiling together, in a leaden vessel, for an hour or two, 1 part by weight of dry and recently-slaked lime, 2 parts of crystallised carbonate of soda (which being cheaper than carbonate of potash, I prefer), and 8 parts of water. The clear and colourless caustic lye, obtained after subsidence, will have a specific gravity of about 1·090, and when drawn off from the sediment, must be kept in a close vessel for use.'

More recently Mr. Peter Spence, of Manchester, has patented a process for obtaining white lead directly from the ores.

As we have before stated, the manufacture of white lead by the Dutch process is one the nature of which seems yet enveloped in considerable obscurity. So far as appearances go, the action would seem to consist: first, in the oxidation of metallic lead by the atmosphere, under the influence of the vapour of acetic acid; secondly, in the production of acetate of lead, by the combination of the oxide of lead with the acetic acid; and thirdly, in the displacement of the acetic acid from its union with the oxide of lead, by the action of carbonic acid, and the consequent formation of white lead. But this in no way accounts for the fact, that, when acetate of lead is decomposed by carbonic acid, it is carbonate of lead, and not white lead, which is formed. Nor can we conceive how an acid like the acetic is capable of being wholly expelled from a metallic oxide by a quantity of another acid incapable of completely saturating the oxide. In other words, as white lead contains free or uncombined oxide of lead, how happens it that the free acetic acid does not remain united to this? We confess our inability to reconcile the facts of the case with the preceding hypothesis, and therefore pass on to another, in which we will assume that acetate of lead, but not the neutral acetate, is formed as we have already supposed. Now there are two subacetates: one composed of six molecules of oxide of lead to one of acetic acid; and the other consisting of three molecules of oxide of lead to one of acetic acid. We select, in preference the former, as it is the one which forms naturally when acetic acid acts, at common temperatures, on an excess of oxide of lead. The composition of this salt is such, that, if we can conceive slow combustion to take place, or that its acetic acid combining with the oxygen of the air is resolved into water and carbonic acid, then the carbonic acid produced would be exactly sufficient to saturate four atoms of the oxide of lead, and leave a compound of the precise composition of white lead. On this view, the first action in a white lead stack would be the production of sexbasic acetate of lead; and the next would be the destruction of this by eremacausis, and the formation of white lead.

The apparatus employed in the manufacture of white lead is extremely simple, and consists merely of certain large enclosures or spaces, called 'beds,' in which the stacks are built up, together with the earthenware-pots needed for holding the vinegar, and the machinery used in casting the lead and grinding the white lead, so as to fit it for the market. The metallic lead was formerly used in the shape of sheets or coils, which were placed perpendicularly over the vinegar pots; but this practice has been almost everywhere abandoned, and at present the lead is generally cast into what are called 'crates' or 'grates,' and having the appearance of lattice-work; the object being to expose as large a surface as possible of metallic lead to the action of the vapour of the vinegar. The beds are of considerable size; and, in this respect, some diversity of opinion prevails amongst practical men; but it seems pretty certain that no advantage is gained when the area of a bed comes to exceed 300 square feet; and there are many reasons for believing that, with beds of twice this area, the gain, in point of diminished labour, is much more than compensated for by the reduced produce in white lead. Nevertheless, each manufacturer seems to entertain an opinion of his own in respect to this matter; and there are even some pretensions to secresy concerning it. In fact, everything depends upon the construction of the bed, for it is this which regulates the production of white lead; and, as a proof of the great importance connected with this circumstance, we may here mention, that, whilst one manufacturer has produced as much as 65 per cent. of corrosion during a long course of years, another in his immediate neighbourhood has never been able to exceed 52 per cent. The beds of the former are 16 feet square, whilst those of the latter are 19½ feet square; and, in dwelling upon the details of this operation, we shall find that theoretically, a bed may be too large, as the above practical fact indicates.

In forming a stack, it is necessary to begin by laying, in the first instance, a bed of spent tanners' bark, 3 feet in thickness, over the surface of the bed; and upon this are placed the earthenware-pots containing the vinegar. These are arranged side by side, and filled to about one-third of their contents with vinegar, of a strength equal to 6 per cent. of anhydrous acetic acid. Upon these pots are placed the crates of lead, and over all a series of boards are arranged, which form a floor for the next layer of spent tan. Such an arrangement as we have described is denominated 'a bed,' but there is this difference between the beds, viz. that the lowest or bottom bed has a bed of tan 3 feet in thickness, whereas but one foot only is needed in the others. Having finished the lowest bed, 12 inches of spent tan are now placed upon the boards, and a similar arrangement of pots, crates, and boards takes place, which constitutes the second bed; this is followed by a third, a fourth, and so on, until at last the uppermost bed is finished; when a layer of spent tan, 30 inches in thickness, is placed over the whole, and the operation may be said to commence. In six or eight days the tan begins to ferment and evolve heat; and this goes on increasing for some weeks, when it gradually diminishes, and at the end of about three months the whole has become cool, and the stack is fit to be taken down. When examined, the pots, which formerly contained vinegar, will now be found to be quite empty, or to hold a little water merely, but no acetic acid; the leaden crates will be discovered to have increased sensibly in bulk, to have become coated with a thick and dense incrustation of white lead, and in some places even to have become altogether converted into this substance; whilst the tan, having lost its fermentative quality, is now useless, except as fuel.

The successive beds constituting the entire stack are next carefully removed, so as to obtain the white lead with the least possible admixture of the tan; and as a portion of this substance always adheres to the crates, these are washed in a kind of wear or trough, by which the whole of the tan is thoroughly separated. When this is seen to be complete, the corroded part of the plate or 'white lead' is detached from the uncorroded or 'blue lead,' either by means of rollers or with a mallet. The blue lead is weighed, and, for the most part, remelted and again cast into crates; whilst the white lead is first crushed, and afterwards ground in water into a fine powder, when it is collected by elutriation and deposition, and dried in stoves, a little below the boiling point of water. Formerly this grinding was performed in the dry way, and much injury to the health of the workmen thus resulted; but for many years past the wet mode of grinding has been general, and is greatly to be preferred.

WHITING. Chalk levigated and carefully washed, after which it is formed into balls.

WICK (*Mèche*, Fr.; *Docht*, Ger.) is a spongy cord, usually made of soft spun cotton threads, which by capillary action draws up the oil in lamps, or the melted tallow or wax in candles, in small successive portions, to be burned. In common wax and tallow candles the wick is formed of parallel threads; in the stearine candles the wick is plaited upon the braiding machine, moistened with a very dilute sulphuric acid, and dried, whereby as it burns it falls to one side and consumes without requiring to be snuffed; in the patent candles of Mr. Palmer one-tenth of the wick is first imbued with subnitrate of bismuth ground up with oil; the whole is then bound round in the manner called *gimping*; and of this wick, twice the length of the intended candle is twisted double round a rod. This rod with its coil being inserted in the axis of the candle-mould is to be enclosed by pouring in the melted tallow; and when the tallow is set the rod is to be drawn out at top, leaving the wick in the candle. As this candle is burned, the ends of the double wick stand out sideways beyond the flame; and the bismuth attached to the cotton being acted on by the oxygen of the atmosphere causes the wick to be completely consumed, and therefore the trouble of snuffing it is saved. See CANDLES.

WINCING MACHINE is the English name of the dyers' reel, which he suspends horizontally, by the ends of its iron axis in bearings, over the edge of the vat, so that the line of the axis, being placed over the middle partition in the copper, will permit the piece of cloth which is wound upon the reel to descend alternately into either compartment of the bath, according as it is turned by hand to the right or the left. See DYEING.

WINE is the fermented juice of the grape. This beverage has been in use from the earliest periods of man's history. We have, however, only space to deal with wine in its modern relations.

In the reign of Elizabeth the wines chiefly in use in England were those of Gascony, Burgundy, and Guienne, which, with Canary, Cyprus, Grecian Malmsey, Italian Vernage, Rhenish Tent, Malaga, and others, were 'accompted of, because of their strength and valure.'

In the time of Charles II. 'the consumption of French wines was two-fifths that of the whole of England. The favourite wines were then Bordeaux, Burgundy, and Hermitage. Champagne, although known in England in the reign of Henry VIII., did not come into use till that of Charles II.

The strong wines of Burgundy, the white wines of Spain (*Sherris-sack* or *Sec*). and the red wines of Portugal, first came into use about 1690 A.D. Port wine was at first a much lighter wine than it afterwards became. According to Baron Forrester, the first Port wine introduced into this country was not from the Douro, or even shipped at Oporto. It was a wine resembling the Claret of Burgundy.

The wine-growing countries are especially the more southern states of Europe, where the grapes, being very saccharine, afford a more abundant production of alcohol, and stronger wines, as exemplified in the best Port, Sherry, and Madeira. In the more temperate climates, such as the district of Burgundy, the finer-flavoured wines are produced; and there the vines are usually grown upon hilly slopes fronting the south, with more or less of an easterly or westerly direction, as on the Côte-d'Or, at a distance from marshes, forests, and rivers, whose vapours might deteriorate the air. The plains of this district, even when possessing a similar or analogous soil, do not produce wines of so agreeable a flavour. The influence of temperature becomes very manifest in countries further north, where, in consequence of a few degrees of thermometric depression, the production of generous, agreeable wine becomes impossible.

The land most favourable to the vine is light, easily permeable to water, but somewhat retentive by its composition; with a sandy subsoil, to allow the excess of moisture to drain readily off. Calcareous soils produce the highly-esteemed wines of the Côte-d'Or; a granitic *débris* forms the foundation of the lands where the Hermitage wines are grown; siliceous soil interspersed with flints furnishes the celebrated wines of Château-Neuf, Ferté, and La Gaude; schistose districts afford also good wine, as that called *la Malgue.* Thus we see that lands differing in chemical composition, but possessed of the proper physical qualities, may produce most agreeable wines. As a striking example of these effects, we may adduce the slopes of the hills which grow the wines of Montrachet. The insulated part towards the top furnishes the wine, called *Chevalier Montrachet*, which is less esteemed, and sells at a much lower price, than the delicious wine grown on the middle height, called *true Montrachet.* Beneath this district and in the surrounding plains the vines afford a far inferior article, called *bastard Montrachet.* The opposite side of the hills produces very indifferent wine. Similar differences, in a greater or less degree, are observable relatively to the districts which grow the Pomard, Volnay, Beaune, Nuits, Clos-de-Vougeôt, Chambertin, Romanée, &c. Everywhere it is found that the reverse side of the hill, the summit and the plain, although generally consisting of like soils, afford inferior wine to the middle southern slopes.

In the district of Médoc the soil is mainly a quartzose gravel, with a subsoil of argillaceous sand, sometimes compacted by brown iron ore, known as *alios,* which in the neighbouring or southern district of Graves becomes more sandy, and marly, overlying the limestones which form considerable cliffs in the neighbouring department of Dordogne. These latter are known as the Côtes, the thin soils above them producing the generous wine of St.-Emilion. Other examples of limestone soils are furnished by the Côte-d'Or, the great wine-producing district of Burgundy, a chain of limestone hills which extends for about 36 miles, from Dijon to Châlons-sur-Saône, and include the famous vineyards of Clos-de-Vougeôt, Chambertin, Nuit-sur-Ravier, &c., which are situated on their eastern slope. In Champagne the soils are mainly a clayey and sandy alluvium above chalky limestones, very usually barren when too exclusively sandy or calcareous, so that it is necessary to dress the soils with clay, in order to produce the fertility required for vine-growing. On the Rhine and the tributary vine-growing valleys of the Maine, Moselle, Lahn, and Ahr, the soils are generally decomposed clay-slate, more or less quartzose, of Devonian age. The vineyards are situated on the steep hill-sides, the soil being retained by terrace-walls, the wash of the winter rains being received by earth carried up in baskets every spring. In the Sherry-producing districts, of the neighbourhood of Cadiz, the finest wines are produced from an argillaceous calcareous soil known as *albariza,* while a lighter and less valuable wine is given in the lower sandy soils or *arenas.* On the southern slopes of the Sierra Nevada, in Spain, the vines grow in a deep natural soil produced from the decomposition of clay-slate, without terracing up to a height of about 3,000 feet above the sea-level. The produce is a sweet wine used in the production of Sherry and Malaga at various places in the south of Spain.

For the vine, a manure supplying azotised or animal nutriment may be used with great advantage, provided care be taken that it may not, by absorption in too crude a state, impart any disagreeable odour to the grape, as sometimes happens to the vines grown in the vicinity of great towns, like Paris, and near Argenteuil. There is a compost used in France called *animalised black,* of which from $\frac{1}{5}$ to $\frac{1}{4}$ of a litre (old English quart) serves sufficiently to fertilise the root of one vine when applied every year or two years. An excess of manure, in rainy seasons especially, has the effect of rendering the grapes large and insipid.

The famous vineyards of Steinberg and Johannisberg, on the Rhine, and Château-Margaux, in Médoc, are heavily manured, each consuming the whole of the manure produced on a large grazing farm of about 600 acres, or from 6 to 8 times its own area.

The ground is tilled at the same time as the manure is applied, towards the month of March; the plants are then dressed, and the props are inserted. The weakness of the plants renders this practice useful; but in some southern districts the stem of the vine, when supported at a proper height acquires, after a while, sufficient size and strength to stand alone. The ends of the props or poles are either dipped in tar, or charred, to prevent their rotting. The bottom of the stem must be covered over with soil after the spring rains have washed it down. The principal husbandry of the vineyard consists in digging or ploughing, to destroy the weeds, and to expose the soil to the influence of the air during the months of May, June, and occasionally in August.

The fruit of the same plant when transferred to a different soil loses its peculiar characteristics; thus one and the same vine produces Hock upon the Rhine, Bucellas in Portugal, and Sercial at Madeira. It has been found that vines from Germany, France, Portugal, and Spain transplanted to the Cape of Good Hope and Australia, have in no one instance produced wine assimilating to the peculiarities of the original plant; and no European vine has hitherto succeeded when transplanted to the United States, although wine is made at Cincinnati from American grapes.

The finest known wines are the produce of soils the combination and proportions of whose ingredients are extremely rare and exceptional; and co-operating with these they require the agency of peculiar degrees of light, moisture, and heat. The district of Xeres, which has so long supplied us with Sherry, is mapped out so accurately by the line of its peculiar soil that its dimensions are known by the acre. The vine which produces Port on the hills above the Douro yields a totally different wine in the vicinity of the Tagus. The wine district of the Rhinegau, between Mayence and Rudesheim, is but 9 miles in length by half as much broad. The south side of a single hill produces Johannisberg; and Steinberg is the vineyard of a suppressed monastery. The numerous wines of Burgundy and the Garonne take their names respectively from circumscribed spots; and so narrow and apparently so capricious are the respective limits, that a ditch divides portions which from time immemorial have been sought with avidity, from others which in the market will uniformly bring but one-fifth the price. The produce of the celebrated vineyard of Lafitte, near Bordeaux, for the year 1848, was sold at 4,000 francs per tun, while the wines of the immediate neighbourhood realised only 200 francs. The proprietor of a vineyard which is only separated from that of Lafitte by a narrow gully, a few years since expended a large sum of money in endeavouring, by improved cultivation, to assimilate his wines to that of Lafitte. To some extent he improved the quality, but the wines never approached the peculiar character of the Lafitte, while the expense incurred was so enormous that the enterprising proprietor was ruined. The costly Clos-de-Vougeôt grows in a farm of 80 acres. Romanée-Conti is but 6½; and the famous Montrachet of the Côte-d'Or is distinguished into three classes, of which one sells at one-third less than the other two, 'yet these qualities are produced from vineyards only separated from one another by a footpath; they have the same aspect, and apparently the same soil, in which the same vines are cultivated and managed in precisely the same manner.'—(*Henderson on Wines.*) One small valley in Madeira alone produces the finest Malmsey. (See Sir Emerson Tennent *On Wine, its Uses and Taxation.*) Art and horticultural science have, he remarks, been applied to extend the limits thus circumscribed by nature, but with such unsatisfactory results, that, as a rule, it may be stated that the higher class wine of any known district has not been successfully reproduced beyond it. The red wines of Portugal grown in the Alto Douro can no more be made in the adjoining provinces of the Minho or Beira than the white wines of Spain could be successfully imitated on the Rhine.

Vine Diseases.—The *Oïdium Tuckeri* is the name given to one of the diseases, Mr. Tucker having first carefully observed the growth of this destructive microscopic fungus. In connection with the cultivation of the vine, and the manufacture of wine, it is necessary that the peculiar characteristics of this disease should be described.

It is stated that the epidemic first showed itself in a hothouse in England in 1845. White efflorescences were remarked, which covered the vine; the grapes were soon after attacked, and, hindered from swelling, the skin burst, and at last they became rotten and fell off. In 1847 it appeared in France; attacking first the hothouses, it spread rapidly to the trellised vines, and to those cultivated near the ground. It then invaded Spain, which it devastated; and finally, in 1851, made its appearance in Italy. This fungus attacks the hinder parts of the vine, and rarely the stems. The leaves and tendrils also become more or less affected, the green colour of those parts becoming paler, and marked with a dark yellow, as if burnt, and emitting an offensive smell. It was fancied at first that the fungus was produced by the puncture of an insect, and its presence was actually ascertained in the seed of the grape, and on the hinder side of the leaf. This insect established itself on the leaves, and formed a cobweb-like film, rising like a blister on the upper part of the leaf. The birth of it is, however, now generally admitted to be posterior to the invasion of the *oïdio.*

The 'Reports of Her Majesty's Secretaries of Embassy and Legation on the Effects of the Vine Disease on the Commerce of the Countries in which they reside' all point to sulphur as the only reliable remedy for this disease. The most practical method of applying sulphur to the vines was that introduced by Dr. Ashby Price. By boiling sulphur and lime together in water we obtain a brilliant yellow solution, which is a sulphide of lime; with a diluted solution of this the vines are washed over every part. By the action of the carbonic acid of the plant it is speedily decomposed, and over every part a thin white film of sulphur is produced, which effectually destroys the parasite without injuring the vine.

Within the last few years the vines of the south of France have been ravaged by a new disease due to the invasion of a parasitic insect named by M. Planchon *Phylloxera vastata.* The first appearance of the disease was in 1865, when it was observed in the neighbourhood of Avignon, Dep. of the Gard. In the following year it spread from this centre, and also appeared in several localities in the Deps. of Vaucluse and the Bouches-du-Rhône. Spreading at first gradually, but afterwards with alarming rapidity, the disease has extended to such an extent that in 1873 it had established itself in no fewer than twelve departments. The dreadful destruction which it causes may be seen by comparing the statistics of the grape-crops of recent years with those of the same localities prior to the appearance of the Phylloxera. For example, in the Commune of Graveson the mean crop just before the year 1865 was 10,000 hectolitres; this amount then became reduced year by year, until in 1873 it reached only 50 hectolitres. In some Communes the crops have been almost entirely destroyed. The Phylloxera, which is undoubtedly the cause of all this mischief, is a very minute insect, measuring not more than 1-33rd of an inch in length. From April to October it continues active, but during the rest of the year it hybernates. When the Phylloxera attacks a vine, the rootlets exhibit peculiar swellings, and the insects multiply so rapidly as soon to overrun all the roots, and by absorbing nourishment from the plant, reduce it to a totally exhausted state. Soon after the disease appeared, the French Academy of Sciences appointed a commission to investigate the subject. Although a large number of remedies have been suggested and tried, it can hardly be said that any of them have as yet (1874) been successful in coping with the difficulty. Perhaps the best means of eradicating the parasite is to place the vineyard under water as soon as the disease appears; but such means evidently admit of only local application.

Vintage.—The vintage, in the temperate provinces, generally takes place about the end of September, and it is deteriorated whenever the fruit is not ripe enough before the 15th or 20th of October; for, in this case, not only is the must more acid and less saccharine, but the atmospheric temperature is apt to fall so low during the nights, as to obstruct more or less its fermentation into wine. The grapes should be plucked in dry weather, at the interval of a few days after they are ripe; being usually gathered in baskets, and transported to the vats in dorsels, sufficiently tight to prevent the juice from running out. Whenever a layer about 14 or 15 inches thick has been spread on the bottom of the vat, the treading operation begins, which is usually repeated after macerating the grapes for some time, when an incipient fermentation has softened the texture of the skin and the interior cells. When the whole bruised grapes are collected in the vat, the juice, by means of a slight fermentation, reacts, upon the colouring-matter of the husks, and also upon the tannin contained in the stones and the fruit-stalks. The process of fermentation is suffered to proceed without any other precaution, except forcing down from time to time the pellicles and pedicles floated up by the carbonic acid to the top.

With whatever kind of apparatus the fermentation may have been regulated, as soon as it ceases to be tumultuous, and the wine is not sensibly saccharine or muddy, it must be racked off from the lees, by means of a spigot, and run into the ripening tuns. The marc being then gently squeezed in a press, affords a tolerably clear wine, which is distributed among the tuns in equal proportions; but the liquor obtained by stronger pressure is reserved for the casks of inferior wine.

In the south of France the fermentation sometimes proceeds too slowly, on account of the must being too saccharine: an accident which is best counteracted by maintaining a temperature of about 65° or 68° Fahr. in the tun-room. When the must, on the other hand, is too thin, and deficient in sugar, it must be partially concentrated by rapid boiling before the whole can be made to ferment into a good wine. By boiling up a part of the must for this purpose, the excess of ferment is at the same time destroyed. Should this concentration be inconvenient, a certain proportion of sugar must be introduced, and immediately after racking it off.

The specific gravity of must varies with the richness and ripeness of the grapes which afford it; being in some cases so low as 1·0627, and in others so high as 1·283. This happens particularly in the south of France. In the district of the Necker in Germany, the spec. grav. varies from 1·050 to 1·090; in Heidelberg, from 1·039 to 1·091, but it varies much in different years.

After the fermentation is complete, the vinous part consists of water, alcohol, a colouring-matter, a peculiar aromatic principle, a little undecomposed sugar, bitartrate and malate of potash, tartrate of lime, chloride of sodium, and tannin; the latter substances being in small proportion.

It is known that a few green grapes are capable of spoiling a whole cask of wine, and therefore they are always allowed to become completely ripe, and even sometimes to undergo a species of slight fermentation before being plucked, which completes the development of the saccharine principle. At other times the grapes are gathered when they are ripe, but are left for a few days on wicker-floors, to sweeten, before being pressed.

In general the whole vintage of the day is pressed in the evening, and the resulting must is received in separate vats. At the end usually of six or eight hours, if the temperature be above 50° Fahr., and if the grapes have not been too cold when plucked, a froth or scum is formed at the surface, which rapidly increases in thickness. After it acquires such a consistency as to crack in several places, it is taken off with a skimmer, and drained; and the thin liquor is returned to the vat. A few hours afterwards another coat of froth is formed, which is removed in like manner, and sometimes a third may be produced. The regular vinous fermentation now begins; characterised by air-bubbles rising up the sides of the staves, with a peculiar whizzing as they break at the surface. At this period all the remaining froth should be quickly skimmed off, and the clear subjacent must be transferred into barrels, where it is left to ripen by a regular fermentation.

The white wines, which might be disposed to become stringy, from a deficient supply of tannin, may be preserved from this malady by a due addition of the footstalks of ripe grapes. The tannin, while it tends to preserve the wines, renders them also more easy to clarify, by the addition of white-of-egg or isinglass.

The white wines should be racked off as soon as the first frosts have made them clear, and at the latest by the end of the February moon. By thus separating the wine from the lees, the fermentation which takes place on the return of spring, and which, if too brisk, would destroy all its sweetness by decomposing the remaining portion of sugar, is avoided or rendered of little consequence.

The characteristic odour possessed by all wines, in a greater or less degree, is produced by a peculiar substance, which possesses the characters of an essential oil. As it is not volatile, it cannot be confounded with the aroma of wine. When large quantities of wine are distilled, an oily substance is obtained towards the end of the operation. This may also be procured from the wine lees which are deposited in the casks after the fermentation has commenced. It forms 1-40,000th part of the wine, and consists of a peculiar acid, and ether, each of which has been called the *œnanthic*. The acid is analogous to the fatty acids, and the ether is liquid, but insoluble in water. The acid is perfectly white when pure, of the consistency of butter at 60°, melts with a moderate heat, reddens litmus, and dissolves in caustic and carbonated alkalis, as well as in alcohol and ether. Œnanthic ether is colourless, has an extremely strong smell of wine, which is almost intoxicating when inhaled, and a powerful disagreeable taste.—*Liebig and Pelouze.*

PORTUGAL.—Port wine is the produce of a single well-defined district in the north of Portugal, extending 8 leagues west and east from the Serra do Marão, an elevation of 4,400 feet above the level of the sea, to the Quinta da Baleira, near San João da Pesqueira, and 4 leagues north and south between Villa Real and Lamego. The returns of the vintages in this area, known as the Alto Douro, from 1843 to 1851, show the average production of qualities fit for use in ordinary years to be 63,568 pipes, in addition to which there are 20,633 pipes of refuse, fit only for distillation; in all 84,211 pipes.

The alcoholic contents of Port wine, as given by Brande, are:—The maximum quality, 23·92; the minimum, 19·82.

Dr. Christison gives the alcoholic contents of Port wine in volume as:—Weak, 18; average of seven kinds, 20; strong, 21.

Red wine of a good character is grown in the vicinity of Figueira, and sometimes shipments have taken place from that port and from Aviero for the English market.

Portugal, in addition to Port wine and its congeners, yields a variety of other wines of a sound and good character; and at one time England consumed, though never very largely, the white wines of Lisbon and Bucellas, and the red wines of the Minho and Beira; but the taste for them changed; it was transferred to the drier and stronger-bodied wines of Spain, and their importation came to an end.

SPAIN.—The Sherries of Spain have long been favourite wines in England and the United States. In 1840, Sir E. Tennent informs us the consumption attained an average of 2,500,000 gallons, and in 1854 it had risen to 2,751,230 gallons. The more recent imports into this country will be seen in the Table at the end of this article.

In the *Basque Provinces* a light wine, called *Chacoli*, is produced, but not in large quantities. Mr. Lumley gives the value of the wines of this district as 17,072*l.*

Alicante produced about 21,118 pipes of wine in 1857.

Valencia produced about 150,000 pipes of 100 gallons each.

Cadiz produces annually from 60,000 to 70,000 butts of new wine (*Mosto*) at about 7*l.* per butt. The Sherries exported from this district are never under three to four years old.

Barcelona is stated to produce 85,000,000 gallons.

Tarragona exports by sea about 35,000 butts, and a large portion is consumed in the province.

Malaga.—Many kinds of grapes are cultivated in this province. The Pedro Ximenes, Doradillo, and Don Bueno are cultivated entirely for the manufacture of wine. The Uvas de Parra or trellis vine, the Passa larga or bloom raisin grape, and the Loja, which is shipped green for England for table use, are cultivated for exportation as fruit. Of Malaga wine the annual produce is on the average about 20,000 butts. Three butts of Malaga wine yield one of brandy, while ten butts of French wine are required to produce the same quantity of spirit. This brandy is used to cure the wines.

Aragon produces a large quantity of wine, those which are most preferred being the wines of Campo de Cariñena. Many of the wine districts of Old Castile produce also large quantities of wine.

'At present many of the Spanish wines are not only so badly made that they will not keep for two years, but their quality is much injured from their being kept and transported in pig-skins.'—*Correspondent of the Secretary of Legation at Madrid.*

Spain produces an enormous quantity of wine which is not suitable for the English market. Mr. Porter estimated that, good, passable, and bad, it amounted to 120,000,000 gallons; but (says Sir E. Tennent) the testimony is concurrent that, except in Andalusia and a few other minor localities, its manufacture is so imperfect, its qualities so peculiar, and its flavour so extraordinary, from carelessness, dirt, and other causes, that it is not presentable in the English market. Dr. Gorman, in his evidence before the House of Commons Committee, says:—'No natural Sherry comes to this country; no wine house will send it; the article you get is a mixed article; if they gave you the natural produce of Xeres it would not suit you; in all probability you would say it was an inferior wine; our taste is artificial, because we are not a wine-drinking people.'

Brande gives the alcohol in Sherry 18·37 the maximum, and 17·00 the minimum, while Dr. Christison gives the following result from his examination:—Weak, 17 in volume; average of 13 old wines, 18; strong, 20; Madre de Xeres, 21.

The *Montillado* of Spain is a wine which appears to depend for its character on the soil, which is a white soil called *albariza*, containing 70 per cent. of carbonate of lime, with alumina, silica, and a little magnesia. The *Manzanilla* is the produce of the *barros*, or red earths, somewhat sandy.

Sicily, as producing the celebrated *Sicilian Marsala*, is perhaps next in importance. Marsala resembles ordinary sherry in many respects; it is, when good, a wholesome, and, as it is technically described in the trade, a *clean* wine. Of Marsala, Sicily produces not less than 2,143,370 gallons. Sicily also produces red wine, but of a very coarse quality.

Madeira and the Canaries produce a wine, the former under the name of the place of its production, being well known. Its consumption has never, however, been very large. The produce of the island has rarely exceeded 25,000 pipes. In 1854 we imported 42,874 gallons.

Cape of Good Hope.—*Cape wine* has never found much favour in this country. In 1854 we imported 275,382 gallons, whereas in 1825 we obtained 670,000 gallons. This wine is used to some extent in the manufacture of 'British wines.'

South African Port and Sherry were at one time sent to the English market; and, as the price was remarkably low as compared with the Portuguese and Spanish wines, a large demand was created; but on the abolition of the differential duties in their favour on the conclusion of the Treaty of Commerce with France, they were unable to compete with the better qualities of wine produced in Europe.

The only Cape wine of any reputation is *Constantia*, a red liqueur wine produced on the farm of J. P. Kloete.

Australia.—Vine-growing and the manufacture of wine is practised in each of the three southern colonies of Australia, New South Wales, Victoria, and South Australia. The total produce being about 1,500,000 gallons annually. The wines are of different qualities, mainly red, and resemble Burgundy or the fuller wines of the South of France. The white wines resemble Sauternes or Muscatel, but all are more or less disguised by the addition of alcohol. Lately, however, this practice has been to a great extent discontinued.

Before we proceed to the more important wines of France and Germany, we must say a few words on—

United States.—*Catawba Wine.*—About the year 1826, 'the Catawba,' a native American grape, was first brought into notice by Major Adlum, who had found it growing in a garden at Georgetown, near Washington. This vine, which is derived from the wild fox grape, has gradually supplanted all others, and is now adopted, almost universally, throughout the United States for making wine. It imparts a very peculiar musty flavour to the wine, displeasing when first tasted to many palates; but this dislike is easily removed by habit, and the wine is much relished in Ohio and Missouri, where it sells readily at good prices.

About 3,000 acres are cultivated as vineyards in the state of Ohio; 500 in Kentucky; 1,000 in Indiana; 500 in Missouri; 500 in Illinois; 100 in Georgia; 300 in North Carolina; and 200 in South Carolina. It is calculated that at least 2,000,000 gallons of wine are now raised in the United States, the value of which may be taken at a dollar and half the gallon. This is in addition to a large amount produced in California.

In the United States the wine-press is constructed much on the same principle as the ordinary screw cider-press. It has an iron screw 3 or 4 inches in diameter, in a strong, upright frame. A box platform, 6 or 7 feet square, of 3-inch plank, is wedged into heavy timbers, and in this a box to contain the mashed grapes is placed, the box being perforated with holes. Bands to fit loosely inside the box, and pieces of scantling to receive the pressure, complete the implement. The power is applied by a strong lever, and the juice runs out through a hole in the floor, and is led into the cellar beneath by means of india-rubber pipes. Before being subjected to pressure, the grapes are bruised in a small wooden mill. When it is intended to make red wine, the grapes mashed by this process are allowed to stand for two or three days, and are then pressed, in order that the colouring-matter in the skins may be absorbed by the grape juice or 'must.' A sample of good Catawba wine examined by Dr. Chapman was found to contain 11·5 per cent. of alcohol.

Large quantities of sparkling wine are made at Cincinnati, and at St. Louis, and sold as sparkling Catawba.

GERMANY.—The principal wine-producing districts of Germany are situated in the Rhine valley and its tributaries; the chief vineyards being in the narrow portion of the river known as the Rheingau, between Mainz and Assmannshausen. The generic name of *Hock*, given to the produce of this district in England, is derived from Hockheim, which is, however, not on the Rhine, but on the north bank of the Main, about 3 miles east of Mainz. The fine wines of the Rheingau are among the most perfect products of the wine-grower's skill; being remarkable for their delicate flavour and bouquet. The first place is held by the low vineyards of Steinberg, belonging to the Prussian Government and Schloss Johannisberg, the property of Prince Metternich. The practice of allowing the grapes to become dead ripe before gathering prevails here, in the same manner as described in the picking of the fine wines of Sauternes. The other principal centres of production in the Rheingau are at Rudesheim, Marcobrunn, and Geisenheim. At Assmannshausen and Ingelheim, red wines are produced from a Burgundy grape. Other red wines are made at Runkel, on the Lahn, and more particularly in the valley of the Ahr, which, under the names of Walportzheimer and Ahrbleichart, is in considerable demand for local consumption at Bonn, Cologne, and other towns on the lower Rhine.

The principal vineyards of the Moselle are situated between Trier (Treves) and Coblentz, the villages giving their names to the best known growths, being Zeltingen, Piesport, and Brauneberg. The wines resemble those of the Rhine valley, but are lighter, and have less flavour. They mature quickly, but will not keep for any length of time.

A considerable amount of effervescing wine is produced at various manufactories (*Schaumweinfabrik*), at Coblentz, and other places on the Rhine; both Rhenish and Moselle wines being so treated. The natural deficiency of saccharine matter in the wine is supplied by the addition of sugar. The so-called muscatel flavour of the sparkling Moselle and Hock is mainly derived from the alcoholic infusion of elder-flowers.

AUSTRIA.—The total average vintage in Austria is estimated at 158,986,000 florins =3,974,650*l.*, while the value of the wine production amounts only to 40,000,000 florins, or about 1,000,000*l.* sterling.

The Austrian wines are on the average but of middling quality; yet there are some which can bear comparison with all but the very best Rhine, French, and Spanish wines. The principal wines of Austria and Hungary are—

'*Red wines*,' grown at Erlan, Carlowitz, Szeksard, Buda, Adelsberg, Villau, and St. André;

'*Schiller wines*,' a pale, reddish-coloured wine, grown at Erlan and Carlowitz;

'*White wines*,' grown at Pesth, Steinbruch-Berg, Totfaln, Moor, Teting, Vöslau, and Rust;

'*Wines of the first press*,' grown at Rust and Oedenburg.

FRANCE.—The chief wine-growing districts of France are Provence, Languedoc, Roussillon, Auvergne, Bourgogne, Saintonge, and Champagne, the rich valleys of the Gard, Hérault, Garonne, Dordogne, the Loire and the Rhône, and the neighbouring departments as far as the Pyrénées, the Hautes-Pyrénées, and the Pyrénées-Orientales.

The average production of wine per annum is between 40,000,000 and 42,000,000 hectolitres (of 22·0096 gallons English).

The following account of the principal French wines is condensed from Viscount Chelsea's Report on the *Effects of the Vine Disease.* He divides France into six principal districts:—

1st. The southern, including Corsica, Roussillon, Languedoc, and Provence.

(*a.*) *Corsican.* Corsica produces both dry and sweet wines, but in quantities too small for exportation.

(*b.*) *Roussillon.* These wines are produced exclusively in the Department of the Pyrénées-Orientales, which contains about 125,000 acres of vineyards. Sweet, dry, and ordinary wines are equally abundant. Strong, rich in colour, and being generous, they keep long, travel well, and are good for mixing with others. There are three recognised varieties, 1st, those of Banyuls, of Collioure, and of Port Vendres, red wines which generally improve with age: 2nd, those of Rivesaltes; the greater portion being ordinary wines of commerce, deep and brilliant in colour; 200 acres alone produce fine wines, as *Muscat*, *Manabes*, *Grenache*, *Malvoisie*, and *Raneio*: 3rd, Perpignay; the wines of this district will keep an indefinite time, and are sent to North and South America.

(*c.*) *Languedoc.* Under this name are included all the wines of the Hérault, Aude, and a part of Gard. The most important of these districts is that of Hérault, producing two kinds of wine; those for conversion into spirit and ordinary wines, which may be subdivided into red and white ordinary wines, fine red wine, white wines, dry and sweet, and Muscats.

Aude. This district produces a red wine at Limoux, and a white wine known by the name of Blanquette, which is nearly double the value of the preceding. Hérault is the most important wine country in the south of France; it is the largest producer of raw spirits in Europe. The red wines of Hérault are produced in the vineyards of St.-Georges-d'Orques; these are generally heady.

The white wines of Picardan include both dry and sweet.

Muscat, *Frontignan*, and *Lunel.* The cultivation of these wines has considerably diminished of late years; they have less flavour and do not keep so well as those of Rivesaltes.

The vineyards of St.-Gilles (Gard) produce a less delicate wine than those of Roussillon, but which serves to bring up the colour of other wines.

(*d.*) *Provence.* The wines of Provence have not the importance of those of Roussillon or of Languedoc. The chief growths of the region are:

1st. In the Var, that of Gande producing a fine wine, at first highly coloured and heady, but becoming dry with age.

2nd. That of Malgue, producing a wine which does not mature, but that bears the sea well.

3rd. That of Bandol, an excellent wine for export, improving much with age: it is sent to India, Brazil, and California.

In the Basses-Alpes, the vineyards of Mées yield a generous wine. In the Bouches-du-Rhône, Cassis produces the finest wines in the region, both red and white, much sought after by foreigners. The sour and flat wines of Roquevaire are little appreciated. The methods of cultivation are nearly the same in all the districts of the south of France. The soil is generally dug up before the vines are planted; in Roussillon only is this omitted, when the ground has been previously cultivated. In the latter, the operation of planting is carried on in January and February; in Languedoc it is put off until April.

With those varieties of the vine which produce the Muscat, it is the custom to rub off part of the buds. The vines are dressed four times during the first year, but afterwards only twice. They commence bearing in from three to four years. The grapes are pressed by the feet or between channelled rollers without being picked off the bunches. The wine is slightly sprinkled with lime or plaster-of-Paris when it is intended for commerce. It is allowed to ferment for ten, twenty, or even thirty days.

2nd. The south-eastern, including Gard, Vaucluse, Ardèche, Drôme, and Rhône. This region embraces all the lower part of the basin of the Rhône; the wines produced are generally known as wines of the Côte-du-Rhône.

(*a.*) That part of *Gard* which is included in this region produces, 1st, the red wine of *Tavel*—very dry, and improving much by age—and the red wine of *Lirac.* 2nd. The sweet wines of *Chusclan*, wines of the finest quality, and those of *Orsan* and *St.-Geniez*, of the second. The Gard also produces the ordinary wines of *St.-Laurent-des-Arbres* and *Roquemaure.*

(*b.*) *Vaucluse.* The chief growths are the *Château-Neuf-du-Pape*, a very celebrated wine, and the growth of *La Nerthe*, which is decreasing both in quality and quantity; it is sent to Bordeaux and Burgundy, for the purpose of colouring other wines. In Vaucluse also are the vineyards of the *Château-Vieux*, of *Nettes*, and of *Etret.*

(*c.*) *Ardèche* includes the famous vineyards of *St.-Peray.* This white wine, when in a state of effervescence, almost equals Champagne, which, however, has more lightness, delicacy, and softness. It is sent to England, Germany, Belgium, and Holland. The best sparkling sort sells at 2 francs 50 centimes the bottle. There are also the vineyards of St.-Jean, Comas, and St.-Joseph. The sparkling wine of St.-Peray is produced in the same way as Champagne.

(*d.*) *Drôme.* The *Hermitage*, the most famous vineyard in the Côte-du-Rhône, consists only of 140 hectares. It produces red wine, white wine, and 'vins de paille' (straw-coloured); the other vineyards are *Larnage*, *Rochegude*, *Crozes*, and *Mercurol*, all of which wines are esteemed.

(*e.*) *Rhône.* The southern part of the Rhône produces wine very similar to the preceding. The best known are of those of *Condrieux* and *St.-Michel.*

The vineyards of the Hermitage are managed with great care; the soil is dry to the depth of a meter (39 inches); the leaves are picked off the vine, and it is dressed and tended five times a year during the first two years; the grapes are stripped off the stalks, and the fermentation lasts ftom fifteen to twenty days.

3rd. The eastern region is formed principally of the Valley of the Saône.

(*a.*) *Beaujolais*, the *Mâconnais*, and the *Côte-Chalonnaise*. These wines are delicate, light, well-flavoured, but not highly-coloured; they are principally consumed in the interior of France. The principal growths are of *Chênas* and that of *Fleury*. The *Mâconnais* produces the highly-esteemed white wine of *Pouilly*, a dry wine which keeps badly, and the red wine of *Romanèche*. The wines of *Côte-Chalonnaise* are common wines, amongst which the *Mercurey* alone is remarkable.

(*b.*) *Haute-Burgogne*, consisting of the Côte-d'Or, produces the most famous wines in Burgundy. The white wines of the Côte-d'Or, most known are those of *Montrachet*, very superior wines; of *Meursault*, very delicate, light, and with a delicious 'bouquet;' and those of Blaquy. It is the red wines, however, which give pre-eminence to this district. Here grow the renowned *Volnay*, *Pomard*, *Beaune*, *Nuits*, more spirituous than the others, and which require to be kept five or six years in the wood; *Vosne*, *Romanée-Conti*, *Clos-de-Vougeôt*, and *Chambertin*.

(*c*). *Basse-Burgogne*. The wines of Lower Burgundy are brisk, delicate, and light, but too spirituous. The *Tonnerre* is fit for drinking after the third year, and the wines of *Auxerrois*, which are sooner matured. In Auxerrois also are the vineyards of *Chablis*; these white wines, so much esteemed for their lightness, are made in the early part of October, under the name of *Chablis*. A large quantity of other white wine from the neighbouring vineyards finds its way into the market. The wines of *Avallonais*, and those of Joigny are sent to Flanders and Belgium.

(*d.*) *Jura*. The wines of this district are in general dry, heady, brisk, but with some acidity, which arises from their bad cultivation and the unskilful mixture of the vines, and reduces their reputation. In addition to the inferior wines, the Jura produces also rose-coloured wines ('*Vins Rosés*'); these are sparkling wines, and the luscious wine known under the name of '*Vin de Garde du Château Chalons*.' This vineyard only comprises 96 hectares. The wines produced there require to be kept from twelve to fifteen years in the cask. All these wines are consumed where they are grown, or sent to Switzerland.

At Seyssel, and other places, in the neighbourhood of Lyons, and in Savoy, a pleasant white sparkling wine is produced and known locally as *Vin-des-Asphaltes*, the vineyards being situated on the asphaltic limestones now so extensively used as a paving material in Paris and London.

(*e.*) *Alsace* produces only common wine, with the exception of the *Turchemi* and *Ribeauviller*.

(*f.*) *Lorraine*. The principal growths are those of *Thiancourt*, *Pagny*, and *Sey*.

(*g.*) *Champagne*. The wines of the Department of the Marne, known under the name of *Champagne*, have a universal reputation.

Champagne Wines are divided into four categories:—*Sparkling Granot*, *Ordinary Sparkling*, *Half Sparkling*, *Tisane de Champagne*.

The following are the principal growths:—

On the Marne	By the Avise	On the Mountains of Rheims
Mareuil.	*Avise.*	*Bouzy.*
Ay.	*Cramant.*	*Ambonnay.*
Hautvillers.	*Oger.*	*Mailly.*
Epernay.	*Mesnil.*	*Sillery.*
		Romont.

The most esteemed kinds are the *Sillery*, *Ay*, *Cramant*, and *Bouzy*. In good seasons this district does not produce less than 15,000,000 bottles of white wine. The average produce is 7,000,000, of which 6,000,000 are sent to England, Russia, and Germany.

The methods employed in Lower Burgundy and Champagne are nearly the same. It is not as respects the cultivation of the plant, but in the methods adopted in making the wine, that the latter is remarkable.

In the manufacture of Champagne black grapes of the first quality are usually employed, especially those gathered upon the vine called by the French *noirien*, cultivated on the best exposures. As it is important, however, to prevent the colouring-matter of the skin from entering into the wine, the juice is squeezed as gently and rapidly as possible. The liquor obtained by a second and a third pressing is reserved for inferior wines, on account of the reddish tint which it acquires. The marc is then mixed with the grapes of the red-wine vats.

The above nearly colourless must is immediately poured into tuns or casks, till about three-fourths of their capacity are filled, when fermentation soon begins. This is allowed to continue for about 15 days, and then three-fourths of the casks are filled up with wine from the rest. The casks are now closed by a bung secured with a piece of hoop-iron nailed to two contiguous staves. The casks should be made of new wood, but not of oak; though old white wine-casks are occasionally used.

In the month of January the clear wine is racked off, and is fined by a small quantity of isinglass dissolved in old wine of the same kind. Forty days afterwards a second fining is required. Sometimes a third may be useful, if the lees be considerable. In the month of May the clear wine is drawn off into bottles. Viscount Chelsea says, 'The wine is bottled between April and August. Warm weather is necesssary to produce the sparkling wine. The effervescence is the result of carbonic acid gas produced by fermentation, which being interrupted in the cask, reproduces and developes itself in the bottles. For this a temperature of from 70° to 75° Fahr. are required. The bottles, as soon as they are filled, which process is effected by women, are handed over to men called "boucheurs," who add a certain quantity of a mixture of brandy and sugar-candy (in the proportion of 15 to 16 per cent. for those wines intended for the English market), taking care to leave about 2½ to 3 inches space between the cork and the wine; they then introduce by a machine a moistened cork, and pass the bottle on to other men called "maillochers," whose business it is to drive the cork home with a mallet, who again transfer them to those who fasten them with a string or wire; sometimes this is done by a machine. It takes an hour to bottle a tun of 88 gallons. The bottles are ranged against the cellar-walls in horizontal layers, each being reversed as it regards the previous layer. Eight or ten days afterwards a deposit, called '*griffe*,' is found at the bottom of the bottle. This indicates the time for removing the bottles to the second or permanent cellar; this is the period also when breakage commences. This loss can neither be foreseen nor prevented, and is often dangerous; it happens mostly at the season when the vine blossoms. The bottles are first placed in the coldest cellars and afterwards removed to warmer temperatures. In the second winter means are taken to remove the deposit formed in the summer; the bottles are placed with their mouths downwards, and are shaken for twenty days, to cause the sediment to fall into the neck. At the end of this time the bottle is uncorked, the sediment thrown out, and a fifth part of the contents replaced by the sweetened liquor, when the bottles are again corked, tied, and stacked as before.' The bottles being filled, and their corks secured by packthread and wire, they are laid on their sides, in this month, with their mouths sloping downwards at an angle of about 20 degrees, in order that any sediment may fall into the neck. At the end of 8 or 10 days the inclination of the bottle is increased, when they are slightly tapped, and placed in a vertical position; so that after the lees are all collected in the neck, the cork is partially removed for an instant, to allow the sediment to be expelled by the pressure of the gas. If the wine be still muddy in the bottles, along with a new dose of *liquor*, a small quantity of fining should be added to each, and the bottles should be placed again in the inverted position. At the end of two or three months the sediment collected over the cork is dexterously discharged; and if the wine be still deficient in transparency, the same process of fining must be repeated.

Sparkling wine (*Vin mousseux*), prepared as above described, is fit for drinking usually at the end of from 18 to 30 months, according to the state of the seasons. It is in Champagne that the lightest, most transparent, and most highly flavoured wines have been hitherto made. The breakage of the bottles in these sparkling wines amounts frequently to 30 per cent., a circumstance which adds greatly to their cost of production. The tension of the carbonic acid gas in the best quality of champagne is from 4½ to 5 atmospheres. If higher, the greater part of the gas is liberated on drawing the cork, and the wine is in great part lost. About 7 or 8 atmospheres is the highest pressure that the bottles will bear without bursting; this is about the working pressure of a high-pressure steam-boiler, from 105 lbs. to 124 lbs. per square inch.

(4.) *Central Region.* In the five departments comprised in this district the common wines alone are produced; the white wine of *Pouilly* being the only celebrated one.

(5.) *Western Region.* The two departments lying on the banks of the Loire, Indre-and-Loire and Maine-and-Loire, possess 40,000 hectares of vineyards; the principal growths are those of *Joué, Bourgueil, Vouvray,* and the white wine of *Saumur.* More than 2,000,000 hectolitres of wine are annually devoted in Aunis, Saintonge, and Angoumois, to the distillation of brandy, so well known as *Cognac.* Of the 200,000 hectares of vineyards in the Charente and Charente-Inferior, only one-third is cultivated for home consumption or exportation, the remaining two-thirds being employed in making brandy. This is divided into two classes, that which is produced in the plain of Champagne in the arrondissement of Cognac, which is again divided, according to the quality, into *Champagne* fine and common *Champagne de Bois,* and *Eau de Vie de Bois,* and that of Aunis, produced from the vines on the banks of the river.

(6.) *South-Western District.* The Gironde and Jurançon are the only localities of any special interest. Although the wines of the Gironde have a common origin, they are divided in commerce into five great classes: *Médoc, De Grave, Des Côtes Palus,* and '*D'Entre Deux-mers.*'

The district known as Médoc, or the promontory between the left bank of the Gironde and sea to the west and north of the city of Bordeaux, is remarkable for the great value and extent of its wine production, the produce of the vineyards of this district being estimated at a value of 11,000,000*l.* in ordinary years. The centre of the trade is at Bordeaux, where the following classification of the different growths is adopted:

1st class. *Premiers Crus.* This includes only three growths: those of Château-Lafitte, Château-Margaux, and Château-Latour.

2nd class. Twelve growths: includes Mouton, Leoville, Larose, and Braue Cautenac.

3rd class. Fourteen growths: including Kirwan, Cautenac, Lagrange, and Giscours.

4th class. Twenty-eight growths: including St.-Pierre, Beycherille, and others in Pauillac and St.-Estèphe districts.

Besides the above, there is a fifth class of named wines, below which the qualities are distinguished as Bourgeois, superior and inferior, and Paysans, the latter being the lowest class.

The proportional scale of prices in an average year may be taken as follows:—

	£		£	
1st class	80	to	200	per tonneau.
2nd ,,	48	,,	56	,,
3rd ,,	32	,,	36	,,
4th ,,	28	,,	36	,,
5th ,,	24	,,	28	,,
Bourgeois, superior	16	,,	20	,,
,, ordinary	14	,,	16	,,
Paysans	12	,,	13	,,

Much of the red wine exported from Bordeaux is fortified with red Hermitage, Spanish red, or other similar Southern wine, for the purpose of increasing its alcoholic strength. The demand for Bordeaux wines is so large and constantly increasing that it would be difficult to meet it without having recourse to sources of supply not lying within the district.

White Wines of the Gironde.—The principal white-wine producing districts in the Gironde are those of Graves and Sauterne, which are on the left bank of the Garonne above Bordeaux.

The most celebrated vineyards are those of Château-Yquem and Château-Latour Blanche. The treatment of the grapes differs from that in other districts, for they are allowed to remain on the vines until they are rotten ripe, and are then gathered berry by berry, care being taken to reject such as may be too far gone, or not sufficiently ripe. By this means a greater amount of saccharine-matter and higher flavour is obtained in the must than is the case in any other wine. Each picking is crushed separately, and the process is so arranged that the vintage of each day is kept apart. The first seven days' collection gives the so-called head wines, *vins de tête*, which are the sweetiest and heaviest; the second or *vins de milieu*, contain less sugar, while the third or *queues*, which are made by pressing all the grapes remaining from the former selections, are the driest. From their great sweetness and strength the highest class of Sauternes require to be kept for several years before their peculiar fineness and richness of flavour is developed. The wines of Château-Yquem when five years old, are valued on the spot at from 400*l.* to 600*l.* per tonneau, according to the vintage.

Such is a somewhat concise statement of the varieties of wines known in commerce. It is not possible to enter into all the details of the manufacture, varying as it does in every locality, the numerous peculiarities being due in some cases to the conditions of the grape itself, and in others to the methods pursued with regard to the fermentation and the subsequent treatment of the wine.

There are many persons who confound the 'flavour' of wine with the 'bouquet.' The differences are well determined by the writer on wine in the 'Penny Cyclopædia.' 'The flavour of wine, called by the French *sève*, indicates the vinous power and the aromatic savour which are felt in the act of swallowing the wine, embalming the mouth, and continuing to be felt after the passage of the liquor. It seems to consist of the impression made by the alcohol and the aromatic particles which are liberated and volatilised as soon as the wine receives the warmth of the mouth and stomach. The *sève* differs from the *bouquet*, inasmuch as the latter declares itself the moment the wine is exposed to the air; it is no criterion of the vinous force or quantity of alcohol present (being, in fact, greatest in weak wines), and influences the organ of smell rather than of taste.'

The *bouquet* of wine is a new product, and in no way dependent on the perfume of the grape from which the wine is made. Red wines scarcely ever retain a trace of the odour of the grapes; the white muscadine wines do in some degree, especially *Frontignan.*

Liebig, in his 'Organic Chemistry,' has the following remarks on the *bouquet*:—'It is well known that wine and fermented liquors generally contain, in addition to alcohol, other substances which could not be detected before their fermentation, and which must therefore have been formed during that process. The smell and taste which distinguish wine from all other fermented liquids are known to depend upon an ether of a volatile and highly combustible acid, which is of an oily nature, and to which the name of *œnanthic ether* has been given.'

On the Rhine an artificial *bouquet* is often given to wine, by hanging orris-root in the casks, or by the use of aromatic herbs.

The volatile substance existing in wine which imparts to it, conjointly with œnanthic ether, its vinous aroma, is partly alcohol. There are other odoriferous substances developed in the course of time; these are compounds of oxide of ethyl, amyl, or propylene, with acetic, propionic, pelargonic, butyric, caproic, caprylic, or capric acids. *Acetic ether* is present in all aromatic wines, and fraudulent dealers will add acetic ether in small quantities to their artificial compounds.

Butyric ether is much used by confectioners, who call it 'pine-apple oil.' *Caprylic ether* has a similar flavour; these are slowly developed in some wines by time. In Watts's 'Dictionary of Chemistry' the other chemical compounds will be found fully described.

Wine produced from grape-juice alone is perfectly colourless or white; but as the whole mass of the grapes is pressed together, it is impossible but that some admixture of the components of the grape-skins should occur. White wine may be prepared from purple grapes, but if the skins are allowed to ferment, red or yellow wine will be obtained. The Italian wine, *Vino Cebedino*, is about the most colourless of wines.

The colour in wines appears to be due to the presence of extractive matter, which, when oxidised, assumes a red or brown colour. This colouring-matter has been called *apothema* by Berzelius, but it is, in fact, humic acid, retaining traces of the substance from which it has been derived.

Whilst the juice of grapes ferments, the skins being present, the wine which is in process of formation extracts tannic acid from the skins, and this gives the yellow colour—when by oxidation it is converted into apothema—to Muscadel, Champagne, Teneriffe, and Madeira.

What we call Red wines are prepared from either black, purple, or red grapes, the juice of which is colourless, and the skins of which are allowed to ferment. During fermentation the weak spirit which is formed extracts not only tannic acid but blue colouring-matter from the skins. This blue colouring-matter is tinged more or less red by the tartaric acid of the wine, and may afterwards be rendered more decidedly red by the formation of acetic acid. In the change of colour undergone by red wine, five periods, according to Mulder, must be distinguished. As soon as alcoholic liquid is formed during fermentation, blue colouring-matter begins to be extracted from the skins. As the small amount of blue colouring-matter is brought into contact with grape-juice, which has an acid reaction, it becomes red. The fermentation and formation of alcohol proceed, as does also the solution of blue colouring-matter, and the young wine is rather blue than red, and may be called 'dark violet.' This new wine now undergoes fermentation, during which a great deal of colouring-matter and red tartar, as well as apothema of tannin and albumen, is precipitated. The loss of the colouring-matter causes the wine to become lighter. In the meantime the formation of acetic acid begins, and at a later period increases; the amount of colouring-matter is not thereby diminished, but the larger proportion of acid in the liquid reddens its colour. Another period now begins, during which the tannic acid is slowly converted into apothema,, whereby red colouring-matter is again precipitated out of the liquid, for example, in Port wine; it thus gradually diminishes, and finally, after a length of time, disappears entirely from the wine, which then remains what is called 'yellow.' This will explain the alterations produced by keeping wines.

According to the character of the wine, as already stated, is its power of enduring unchanged, or of improving by age. Weak wines of bad growths ought to be consumed within twelve or fifteen months after being manufactured; and should be kept meanwhile in cool cellars. White wines of middling strength ought to be kept in casks constantly full, and carefully excluded from contact of air, and the racking off should be done as quickly as possible. As the most of them are injured by too much fermentation, this process should be so regulated as always to leave a little sugar undecomposed. It is useful to counteract the absorption of oxygen, and the consequent tendency to acidity, by burning a sulphur-match in the casks into which they are about to be run. This is done by hooking the match to a bent wire, kindling and suspending it within the cask through the bung-hole. Immediately on withdrawing the match, the cask should be corked, if the wine be not ready for transfer. If the burning sulphur be extinguished on plunging it into the cask, it is a proof of the cask being unsound, and unfit for receiving the wine; in which case it should be well cleansed, first with lime-water, then with very dilute sulphuric acid, and lastly with boiling water.

Wine-cellars ought to be dry at bottom, floored with flags, have windows opening to the north, be so much sunk below the level of the adjoining ground as to possess a nearly uniform temperature in summer and winter; and be at such a distance from a frequented highway or street as not to suffer vibration from the motion of carriages.

Wines should be racked off in cool weather; the end of February being the fittest time for light wines. Strong wines are not racked off till they have stood a year or eighteen months upon the lees, to promote their slow or insensible fermentation. A syphon well managed serves better than a faucet to draw off wine clear from the sediment. White wines, before being bottled, should be fined with isinglass; red wines are usually fined with white-of-egg beat up into a froth, and mixed with two or three times their bulk of water. But some strong wines, which are a little harsh from excess of tannin, are fined with a little sheep or bullock's blood. Occasionally a small quantity of sweet glue is used for this purpose.

For further information, see 'Chemistry of Wine,' by G. J. Mulder, edited by H. Bence Jones, M.D. F.R.S.; and Watts's 'Dictionary of Chemistry.' Also a 'Treatise on Wine,' by Thudicum and Dupré, London, 1872. This is the most comprehensive work on the subject in the English language.

The following Maladies of Wines are certain accidental deteriorations, to which remedies should be speedily applied:—

La-Pousse ('pushing out of the cask'), is a name given to a violent fermentative movement, which occasionally supervenes after the wine has been run off into the casks. If these have been tightly closed, the interior pressure may increase to such a degree as to burst the hoops, or cause the seams of the staves or ends to open. One remedy is, to transfer the wine into a cask previously fumigated with burning sulphur; another is, to add to it about 1000th part of sulphite of lime; and a third, and perhaps the safest, is to introduce ½ lb. of mustard-seed into each barrel. At any rate the wines should be fined whenever the movements are allayed, to remove the floating ferment which has been the cause of the mischief.

Turning Sour.—The production of too much acid in a wine is a proof of its containing originally too little alcohol, of its being exposed too largely to the air, or to vibration, or to too high a temperature in the cellar. The best thing to be done in this case is, to mix it with its bulk of a stronger wine in a less advanced state, to fine the mixture, to bottle it, and to consume it as soon as possible, for it will never prove a good keeping wine.

TABLE I.

Name of the wine	Sp. grav.	100 measures contain at 60° Fahr.		Name of the wine, spirit, &c.	Sp. grav.	100 measures contain at 60° Fahr.	
		Alcohol of 0·825	Absolute alcohol			Alcohol of 0·825	Absolute alcohol
Port wine	0·97616	21·40	19·82	Frontignan	0·98452	17·79	11·84
"	0·97200	25·83	23·92	Côte-Roti	0·98495	12·27	11·38
Mean	0·97460	23·49	21·75	Roussillon	0·98005	17·24	15·96
Madeira	0·97810	19·34	17·91	Cape Madeira	0·97924	18·11	16·77
"	0·97333	21·42	22·61	Muscat	0·97913	18·25	17·00
Sherry	0·97913	18·25	17·00	Constantia	0·97770	19·75	18·29
"	0·97700	19·83	18·37	Tinto	0·98399	13·30	12·32
Bordeaux, Claret	0·97410	12·91	11·95	Schiraz	0·98176	15·52	4·35
"	0·97092	16·32	15·11	Syracuse	0·98200	15·28	4·15
Calcavella	0·97920	18·10	16·76	Nice	0·98263	14·63	13·64
Lisbon	0·97846	18·94	17·45	Tokay	0·98760	9·88	9·15
Malaga	0·98000	17·26	15·98	Raisin wine	0·97205	25·77	23·86
Bucellas	0·97890	18·42	17·22	Drained grape wine	0·97925	18·11	16·77
Red Madeira	0·97899	18·49	17·04	Lachrymæ Christi	..	19·70	18·24
Malmsey	0·98090	16·40	15·91	Currant wine	0·97696	20·55	19·03
Marsala	0·98190	15·26	14·31	Gooseberry wine	0·98550	11·84	10·96
"	0·98000	17·26	15·98	Elder wine Cyder Perry	0·98760	9·87	9·14
Champagne (rose)	0·98608	11·30	10·46				
" (white)	0·98458	12·80	11·84				
Burgundy	0·98300	14·53	13·34	Brown stout	0·99116	6·80	6·30
"	0·98540	11·95	11·06	Ale	0·98873	8·88	8·00
White Hermitage	0·97990	17·43	16·14	Porter	..	4·20	3·89
Red "	0·98495	12·32	11·40	Rum	0·93494	53·68	49·71
Hock	0·98290	14·37	13·31	Hollands	0·93855	51·60	47·77
"	0·98873	8·88	8·00	Scotch whisky	..	54·32	50·20
Vin de Grave	0·98450	12·80	11·80	Irish whisky	..	53·90	49·91

Ropiness or Viscidity of Wines.—The cause of this phenomenon, which renders wine unfit for drinking, was altogether unknown, till M. François, an apothecary of Nantes, demonstrated that it was owing to an azotised matter, analogous to gluten; and, in fact, it is the white wines, especially those which contain the least tannin, which are subject to this malady. He also pointed out the proper remedy, in the addition of tannin under a rather agreeable form, namely, the bruised berries of the mountain-ash (*sorbier*) in a somewhat unripe state; of which 1 lb. well stirred in, is sufficient for a barrel. After agitation, the wine is to be left in repose for a day or two, and then racked off. The tannin by this time will have separated the azotised matter from the liquor, and removed the ropiness. This wine is to be fined and bottled off.

The taste of the cask, which sometimes happens to wine put into casks which have remained long empty, is best remedied by agitating the wine for some time with a spoonful of olive oil. An essential oil, the chief cause of the bad taste, combines with the fixed oil, and rises with it to the surface.

The quantity of alcohol contained in different wines has been made the subject of elaborate experiments by Brande and Fontenelle, and several others; but as it must evidently vary with different seasons, the results can be received merely as approximate. The proportion given by Brande (Table I. page 1147), has been reduced to the standard of absolute alcohol by Fesser; and that by Fontenelle (Table II.), to the same standard by Schubarth, as in the following Tables. Table III. gives the alcoholic strength of the Rhine wines.

TABLE II.

Name of the wine	Absolute alcohol	Name of the wine	Absolute alcohol
Roussillon (Eastern Pyrenees.)		*Department of l'Hérault.*	
		Nissau . . 9 years old	7·896
Rivesaltes . 18 years old	9·156	Béziers . . 8 "	7·728
Banyuls . . 18 "	9·223	Montagnac . 10 "	8·108
Collioure . . 15 "	9·080	Mèze . . 10 "	7·812
Salces . . 10 "	8·580	Montpellier . 5 "	7·413
		Lunel . . 8 "	7·564
Department of the Aude.		Frontignan . 5 "	7·098
		Red Hermitage 4 "	5·838
		White "	7·056
Fitou and Leucaté 10 yrs. old	8·568	Burgundy . 4 "	6·195
Lapalme . . 10 "	8·790	Grave . . 3 "	5·838
Sijeau . . 8 "	8·635	Champagne (sparkling). .	5·880
Narbonne . . 8 "	8·379	" white " . .	5·145
Lezignan . . 10 "	8·173	" rose . . .	4·956
Mirepeisset . 10 "	8·589	Bordeaux	6·186
Carcassonne . 8 "	7·190	Toulouse	5·027

TABLE III.—RHINE WINES.

Place of growth	Sort of grapes	Specific gravity	100 parts yielded	
			Absolute alcohol	Dry residue
Steinberg . . .	Riesling	1·0025	10·87	9·94
Rüdesheim . . .	Orléans	1·0025	12·65	5·39
Markobrunn . .	Riesling	0·9985	11·60	5·10
Geisenheim . . .	...	0·9935	12·60	3·05
Dirnheim . . .	...	0·9925	9·84	2·18
Weinheim Hulberg .	...	0·9925	11·70	2·18
Worms, Liebfrauenmilch	...	0·9930	10·62	2·27
Bingen, Scharlachberg .	...	not determined	12·10	not determined
Eisler, Kleimberger .	...	...	11·90	...
Wiesbaden . . } Neroberg . . }	...	0·9950	10·83	2·78
Wiesloch . . .	...	0·9945	9·83	2·48

From the known prices of these wines, it is obvious that the proportion of alcohol, although one factor in determining the value of a wine, is not the only absolute one nor does it stand in any fixed relation to the commercial value of the wine. It is remarkable that the finest sorts of wines contain a much greater proportion of solid substances in solution than the inferior sorts; and that the weight of the residue, which the Rhenish wines yield on evaporation, offers a safer criterion for determining their commercial value than the proportion of alcohol. These solids disguise the acid, take off the acrid taste, and at the same time impart body, mellowness, and oiliness. Among the extractive matters of new wines are sugar, which gradually disappears by keeping; and also some imperfectly known gummy substances, which become brownish when the wine is submitted to evaporation. The presence of these in wine appears chiefly to be determined by the soil, and the condition and locality of the vineyard; and it is obvious that the qualities dependent upon these extractive matters cannot by replaced by sugar.

Port is one of the wines which is richest in alcohol. Ginjal has stated that genuine Port wines never contain more than 12·75 per cent. of pure alcohol.

With regard to alcoholic contents, Madeira ranks next to Port wine, in which respect they differ but little from each other. Liquor wines are as a rule stronger than red wines. Jurançon, Lachrymæ Christi, Benicario, and Sauterne, all contain from 12 to 15 per cent. alcohol and more. Red French wines contain less—from 9 to 14 per cent. Good Bordeaux contains 10, 11, 12 per cent. Burgundy 9, 10, 11 per cent. Champagne 10, 11 per cent. Rhine wine from 6 to 12 per cent., generally from 9 to 10 per cent.—*Mulder*.

Under the title of the 'Deacidification of Wines,' Professor Liebig published in his *Annalen* a process for effecting that valuable object on old stored (*alte abgelagerte*) Rhine wines. 'Most of these wines,' he says, 'even of the most propitious growths, and in the best condition, contain a certain quantity of free tartaric acid, on whose presence many of their essential properties depend. The juice of all sorts of grapes contains bitartrate of potash, and that of those of the young shoots, in good years, is saturated with it. When the must of these sorts of grapes becomes fermented, the tartar diminishes in solubility proportionally as the alcohol increases, and a part of it falls along with the yeast. This deposit of tartar increases during the first years of the vatting; the sides of the casks become encrusted more and more with its crystals, in consequence of the continual addition of the new wine to replace what of the liquid is lost by evaporation, so as to keep the casks full, and prevent the destruction of the whole. But this deposition has a limit. By the filling up, the wine receives a certain quantity of free tartaric acid, and thereby acquires, at a certain point of concentration, the faculty of re-dissolving the deposited tartar. In the storing of many of the finer wines, the tartar again disappears at a certain period. By progressive filling up, the proportion of acid proportionally augments, the taste and flavour of the wine are exalted, but the acid contents make the wine less agreeable in use. Amateurs and manufacturers should therefore welcome a means of taking away the free tartaric acid without altering in any respect the quality of the wine. This is pure neutral tartrate of potash. When this salt, in concentrated solution, is added to such a fluid as the above, there results the sparingly soluble tartar (one part of which requires from 180 to 200 parts of water of ordinary temperature for its solution), the free acid combines with the neutral salt, and separates as bitartrate from the liquid. If we add to 100 parts of a wine which contains one part of free tartaric acid, one and a half part of neutral tartrate of potash, there will separate by rest at 18°—19° Cent., 2 parts of crystalline tartar, and the wine contains now one half part of tartar dissolved, in which there are only 0·2 part of the original free acid. In this case 0·8 of the free acid has been withdrawn from the wine.'

Wines, British, are made either from infusions of dried grapes (raisins) or from the juices of native fruits, properly fermented. These wines are called *sweets* in the language of the Excise, under whose superintendence they were placed till 1834, when the duties upon them were repealed, as onerous to the trade and unproductive to the revenue. The raisins called Lexias are said to produce a dry flavoured wine; the Denias a sweet wine; the black Smyrnas a strong-bodied wine, and the red Smyrnas and Valencias a rich and full wine. The early spring months are the fittest time for this wine-manufacture. The masses of raisins, on being taken out of the packages, are either beaten with mallets or crushed between rollers in order to loosen them, and are then steeped in water in large vats, between a perforated board at bottom and another at top. The water being after some time drawn off the swollen and softened fruit, pressure is applied to the upper board to extract all the soluble sweet matter, which passes down through the false bottom, and flows off by an appropriate pipe into fermenting tuns. The residuary fruit is infused with additional water, and then squeezed: a process which is repeated till all the sweets are drained off, after which the 'rape' is subjected to severe pressure in a screw or hydraulic press. The wine, in the process of the vinous fermentation, is occasionally passed through a great body of the rape to improve its flavour, and also to modify the fermentative action; it is afterwards set to ripen in casks, clarified by being repeatedly racked off, and fined with isinglass.

Total of all kinds of Wine Imported in 1873.

	Gallons	Value
From Germany	495,930	£77,307
„ Holland	574,943	378,486
„ Belgium	27,287	17,160
„ France	6,242,856	3,135,034
„ Portugal	4,037,594	1,358,241
„ Madeira	80,532	45,391
„ Spain	9,389,367	3,033,113
„ Canary Islands	6,691	1,946
„ Italy	639,514	130,266
„ Channel Islands	33,605	16,500
„ Gibraltar	14,975	8,519
„ Malta	22,819	6,711
„ British Possessions in South Africa .	17,878	10,957
„ British India	24,167	15,847
„ Australia	37,142	11,949
„ Other countries	37,056	19,899
Total	21,682,356	8,267,326

Of this, of Red wine there were 10,049,255 gallons.
„ White „ 11,633,101 „

The quantity entered for home consumption was 18,027,308 gallons. and the amount received for duty was 1,775,903*l.*

The following shows the quantity entered for home consumption and the amount of duty received, so far as regards the importations from France, Portugal and Spain.

	Red		White	
	Gallons	£	Gallons	£
France . .	4,099,799	216,426	1,614,637	83,535
Portugal .	3,451,740	430,857	22,629	2,779
Spain . .	1,057,257	130,266	6,034,257	743,807

Wine Imports in 1874.

	Gallons	Value
Red wine	9,012,696	£2,619,889
White wine	9,261,442	4,248,252

Entered for Home Consumption.

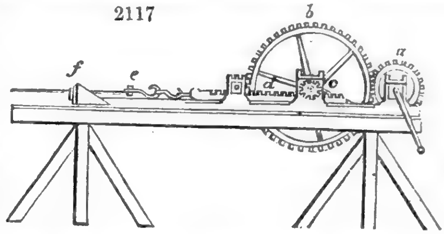
Red wine	8,461,705 gallons
White wine	8,822,680 „

WINE-STONE is the deposit of crude tartar, called 'argal,' which settles on the sides and bottoms of wine-casks. See WINE.

WIRE-DRAWING. (*Tréfilerie*, Fr.; *Drahtziehen*, *Drahtzug*, Ger.) When an oblong lump of metal is forced through a series of progressively diminishing apertures in a steel plate, so as to assume in its cross-section the form and dimensions of the last hole, and to be augmented in length at the expense of its thickness, it is said to be wire-drawn. The piece of steel called the *draw-plate* is pierced with a regular gradation of holes, from the largest to the smallest; and the machine for overcoming the lateral adhesion of the metallic particles to one another is called the *draw-bench.* The pincers which lay hold of the extremity of the wire, to pull it through the successive holes, are adapted to bite it firmly, by having the inside of the jaws cut like a file. For drawing thick rods of gilt silver down into stout wire, the hydraulic press has been had recourse to with advantage.

Fig. 2117 represents a convenient form of the draw-bench, where the power is applied by a toothed wheel, pinion, and rack-work, moved by the hands of one or two men working at a winch; the motion being so regulated by a fly-wheel, that it does not proceed in fits and starts, and cause inequalities in the wire. The metal requires to be annealed, now and then, between successive drawings, as otherwise it would become too hard and brittle for further extension. The reel upon which it is wound is sometimes mounted in a cistern of sour small beer, for the purpose of clearing off, or loosening at least, any crust of oxide formed in the annealing, before the wire enters the draw-plate.

2117



When, for very accurate purposes of science or the arts, a considerable length of uniform wire is to be drawn, a plate, with one or more jewelled holes, that is, filled with one or more perforated rubies, sapphires, or chrysolites, can alone be trusted to, because the holes even in the best steel become rapidly wider by abrasion. Through a hole in a ruby 0·0033 of an inch in diameter, a silver wire 170 miles long has been drawn, which possessed at the end the very same section as at the beginning: a result determined by weighing portions of equal length, as also by measuring it with a micrometer. The hole in an ordinary draw-plate of soft steel becomes so wide, by drawing 14,000 fathoms of brass wire, that it requires to be narrowed before the original sized wire can be again obtained.

Wire, by being diminished one-half, one-third, one-fourth, &c., in diameter, is augmented in length respectively four, nine, sixteen times, &c. The speed with which it may be prudently drawn out depends upon the ductility and tenacity of the metal; but may be always increased the more the wire becomes attenuated, because its particles progressively assume more and more of the filamentous form, and accommodate themselves more readily to the extending force. Iron and brass wires, of 0·3 inch in diameter, bear drawing at the rate of from 12 to 15 inches per second; but when of 0·025 ($\frac{1}{40}$) of an inch, at the rate of from 40 to 45 inches in the same time. Finer silver and copper wire may be extended from 60 to 70 inches per second.

By enclosing a wire of platinum within one of silver ten times thicker, and drawing down the compound wire till it be $\frac{1}{300}$ of an inch, a wire of platinum of $\frac{1}{3000}$ of an inch will exist in its centre, which may be obtained apart, by dissolving the silver away in nitric acid. This pretty experiment was first made by Dr. Wollaston.

The French draw-plates are so much esteemed, that one of the best of them used to be sold in this country for its weight in silver. The holes are formed with a steel punch; being made large on that side where the wire enters, and diminishing with a regular taper to the other side.

WIRE-ROPE. The manufacture of ropes made of wire has, of late years, become a most important one. Not only are ropes of this description now employed in the most extensive coal mines of this country, and for winding generally, but they are used for much of the standing rigging of ships, and for numerous ordinary purposes. Perhaps the most important application of wire-rope has been, however, in the construction of the electric cables. See Electro-telegraphy.

The Tables on the following page show the relative values of ropes of hemp, iron, and steel.

The applications of wire are extraordinarily numerous and interesting. Many thousands of lives are every day trusted to wire in the form of wire-rope for collieries and mines, and the lives of the men ascending and descending a coal pit literally depend from these iron threads. The standing rigging of ships is now generally made of wire-rope. The introduction of telegraphy has given great development to the manufacture of wire. The conducting portion of submarine electric telegraph cables is simply a wire-rope made of copper wires, while the outside protective sheathing generally consists of iron wire. One of the most important applications of wire of late years is that of steel wire in the form of the wire-rope used for

TABLE I.

Round Wire Ropes, for inclined planes, mines, collieries, ships' standing rigging, &c.

Hemp		Iron		Steel		Equivalent strength	
Circumference	Lbs. weight per fathom	Circumference	Lbs. weight per fathom	Circumference	Lbs. weight per fathom	Working load	Breaking strain
						Cwts.	Tons
2¾	2	1	1	...	...	6	2
...	...	1½	1½	1	1	9	3
3¾	4	1⅝	2	...	...	12	4
...	...	1¾	2½	1½	1½	15	5
4½	5	1⅞	3	...	...	18	6
...	...	2	3½	1⅝	2	21	7
5½	7	2⅛	4	1¾	2½	24	8
...	...	2¼	4½	...	...	27	9
6	9	2⅜	5	1⅞	3	30	10
...	...	2½	5½	...	...	33	11
6½	10	2⅝	6	2	3½	36	12
...	...	2¾	6½	2⅛	4	39	13
7	12	2⅞	7	2¼	4½	42	14
...	...	3	7½	...	...	45	15
7½	14	3⅛	8	2⅜	5	48	16
...	...	3¼	8½	...	...	51	17
8	16	3⅜	9	2½	5½	54	18
...	...	3½	10	2⅝	6	60	20
8½	18	3⅝	11	2¾	6½	66	22
...	...	3¾	12	...	...	72	24
9½	22	3⅞	13	3¼	8	78	26
10	26	4	14	...	...	84	28
...	...	4¼	15	3⅜	9	90	30
11	30	4⅜	16	...	...	96	32
...	...	4½	18	3½	10	108	36
12	34	4⅝	20	3¾	12	120	40

Round rope in pit-shafts must be worked to the same load as flat ropes.

TABLE II.

Flat Wire Ropes, for pits, hoists, &c. &c.

Hemp		Iron		Steel		Equivalent strength	
Size in inches	Lbs. weight per fathom	Size in inches	Lbs. weight per fathom	Size in inches	Lbs. weight per fathom	Working load	Breaking strain
						Cwts.	Tons
4 × 1⅛	20	2¼ × ½	11	...	...	44	20
5 × 1¼	24	2½ ×	13	...	...	52	23
5½ × 1⅜	26	2¾ × ⅝	15	...	...	60	27
5¾ × 1½	28	3 ×	16	2 × ½	10	64	28
6 × 1½	30	3¼ ×	18	2¼ × ½	11	72	32
7 × 1⅞	36	3½ ×	20	×	12	80	36
8¼ × 2⅛	40	3¾ × 11/16	22	2½ × ½	13	88	40
8½ × 2¼	45	4 ×	25	2¾ × ⅜	15	110	45
9 × 2½	50	4¼ × ¾	28	3 ×	16	112	50
9½ × 2⅜	55	4½ ×	32	3¼ ×	18	128	56
10 × 2½	60	4⅝ ×	34	3½ ×	20	136	60

steam ploughing, and it may safely be said that steam ploughing would have remained an impossible project without the steel wire-rope. The very great distances, often reaching to 300 yards or more, to which the power is carried by means of the wire-rope in steam ploughing, would seem to point to its application to other purposes in which power is required to be transmitted to great distances. Many and varied are what may be termed the domestic applications of wire. Wire fences, bell-pulls, and, in the form of gauze, to ventilators, are only a few of these. Another most interesting employment of wire, even in a strictly scientific sense, is for the strings of pianofortes. Steel wire is now solely used for this purpose. Professor W. Pole, at the request of the Messrs. Broadwood, the pianoforte-makers, some time ago made a number of experiments on this kind of wire; of which he gave a short account at the Birmingham Institution of Mechanical Engineers. Some of the steel wire he tested, which was made in Germany, bore as much as 110 and 120 tons to the square inch, or about double the breaking strength of good steel. Suspension bridges, a few years ago, used to be made very extensively of wire. The two most celebrated erections of this kind are those of Niagara and Freiberg; the wire of the first was made in Manchester, and broke at 40 tons to the square inch, while that of Freiberg was made in Switzerland, and stood 50 tons to the square inch. The carding of wool and cotton is also effected by means of wire. Brushes of all kinds are now made of steel and iron in this form, even hair-brushes. It is more than probable that wire would be much more used for constructive purposes if some good and generally applicable means for preventing the corrosion of iron and steel could be brought forward. In fact, that is, for all applications of iron, almost the problem of the day. It has been noticed by careful observers that, though Swedish charcoal iron-wire has about the same ultimate breaking tensile strength as other wire, it is nevertheless much more economical than common wire for rope and other purposes in which elasticity and suppleness are required—another proof that breaking strength alone is a very unreliable quality.

The ultimate strength of wire generally, and especially that of iron and steel wire, almost always decreases as the diameter increases—as is also the case with forged and rolled bars, in which the metals are united in greater bulk. Some very small kinds of charcoal wire only break with loads of about 100 tons to the square inch; while the average strength of wire may be taken as double that of rolled bar. Rolled bars, of various qualities, possess breaking strengths ranging from 20 to 40 tons to the square inch, and iron wire will, on an average, be also found to vary from 40 to even 80 tons to the square inch. The most extensive series of experiments on wires has been due to M. Leblanc, who built a rather considerable bridge of wire at Roche-Bernard, in France. Amongst other important inquiries, he also investigated the question whether wires of a great length did not give less resistance than shorter lengths on account of the probable greater number of flaws. He thus took from twelve sets of different wire twelve pieces two meters long and twelve pieces twenty-six meters long, and submitted them to tensile loads. The wire was rather more than one-eighth of an inch in diameter. The resistance of the short pieces was found to be almost the same as that of the long lengths. By means of some experiments extending over a lengthened period, M. Leblanc also found that a wire can support during three months a tension at least equal to nine-tenths of that which would break it without diminishing its ultimate breaking strength, though undergoing elongations of 0·00596 of its original length. General Morin also carried out, some years ago, a number of experiments on long lengths of wire, in order to determine the important question whether wires take a permanent set with the smallest loads: a fact maintained by Mr. Hodgkinson, and which would appear to militate against the doctrine of the elastic limit. The trials were conducted with very great nicety, and their results seem to show that the permanent sets observed by Mr. Hodgkinson were due to the bends taken by the wire when coiled, and which afterwards get stretched out under the loads, as also partly to variations of temperature. In general it may be observed that wire, as compared with bar iron, seems to be better for undergoing impulsive forces, as it is perfectly elastic under loads which, cross-section for cross-section, would break rolled or forged iron. Both rolled iron and wire seem to be able to support for a length of time static loads of an amount very near that which would produce rupture. The elongations are also in proportion to the loads, but this proportionality seems to cease sooner with wire than with wrought iron. The irregularity of the elongations begins with wrought iron with loads of about half the breaking loads, and with wire at about one-third or one-fourth of the load that would cause rupture. Annealing, or cooling down slowly from a red heat, has the same effect on wire as on wrought iron; that is to say, the ductility, and the softness, of both is increased, but their elasticity, and also breaking strength, are considerably diminished. But few experiments have yet been published on the strength and other mechanical qualities of steel wire. It may, however, be taken to have, on an average, twice the ultimate strength of iron wire, and a proportionately greater elasticity, comparing diameter with diameter. These qualities allow steel wire-rope to be made little more than half the weight of iron wire-rope, with the same ultimate breaking strength. The additional elasticity of steel wire and of steel wire-rope renders it much more supple, and less liable to injury through being bent over a drum. A steel rope easily straightens of itself after being bent even to a small angle, which is not the case with iron wire-rope. The duration of all ropes is very greatly influenced by the many bendings to and fro to which they are subjected, and these influences are intensified by corrosion. Both the mechanical and the chemical sources of deterioration act in a less degree on steel wire, as it is stronger, and is, at the same time, less subject to corrosion, as the carbon it contains, however slight, greatly impedes the action of rust. It has been proved that wire-rope which is made of soft annealed wire cannot stand one-quarter or one-sixth of the bending to and fro that it can stand if made of the same wire after it has been hardened. It is to be noticed that, although it can matter but little as regards absolute length whether a wire-rope elongates or takes a permanent set, in practice this is not the case as to its cross-section or the arrangement of its strands, which is injured if the material too easily takes a permanent set. It is easy to imagine cases in which this very softness and ductility is cf great value. In the same way we should imagine that the best pianoforte-wire ought to have a certain elastic limit or a limit up to which it will elongate temporarily without taking a permanent set, and a certain amount of ductility or power of elongation without rupture, while it should have a certain ultimate breaking strength. The same is the case with the other many applications of wire; most of which, however, will be best suited by a high limit of elasticity, or the power of elongating temporarily without taking a permanent set. The principal seat of the iron wire manufacture in England is Birmingham. The most important improvement to be looked for in the wire manufacture is some easy and cheap means of drawing very long lengths of wire.

WOAD (*Guède*, *Pastel*, Fr.; *Waid*, Ger.; *Guado*, It.), the *Isatis tinctoria*, Linn., is almost the only plant growing in the temperate zone which is known to produce indigo. It is an herbaceous, biennial plant, belonging to the natural order *Cruciferæ*, and bears yellow flowers and large flattened seed-vessels, which are often streaked with purple. The leaves, which are the only part of the plant employed in dyeing, are large, smooth, and glaucous, like cabbage-leaves, but exhibit no external indication of the presence of any blue colouring-matter, which indeed, according to modern researches, is not contained in them ready formed. The plant called by the Romans *glastum*, with which, according to Pliny, the Britons, dyed their skins blue, is supposed to be identical with woad. Before the introduction of indigo into the dye-houses of Europe, woad was generally used for dyeing blue, and was extensively cultivated in various districts of Europe, such as Thuringia, in Germany; Languedoc, in France; and Piedmont, in Italy. To these districts its cultivation was a source of great wealth. Beruni, a rich woad manufacturer of Toulouse, became surety for the payment of the ransom of his king, Francis I., then a prisoner of Charles V., in Spain. The term *Pays de cocaigne*, denoting a land of great wealth and fertility, is indeed supposed to be derived from the circumstance that the woad balls, called in French *cocaignes*, were manufactured chiefly in Languedoc.

The woad-leaves were not employed by the dyer in their crude state, but were previously subjected to a process of fermentation, for the purpose of eliminating the colouring-matter. The seed having been sown in winter, or early spring, the plants were allowed to grow until the leaves were about a span long, and had assumed the rich glaucous appearance indicative of maturity, when they were stripped or cut off. The cropping was repeated several times, at intervals of five or six weeks, until the approach of winter put a stop to the growth of the plant. The leaves set up in the succeeding spring yielded only an inferior article (called in German *Komposwaid*), and it was therefore customary to keep only as many plants until the following year as were required for obtaining seed, which, the plant being biennial, is only produced in the second year. The leaves, after being gathered, were slightly dried, and then ground in a mill to a paste. In Germany it was usual to lay this paste into a heap for about twenty-four hours, and then form it by hand into large balls, which were first dried partially in the sun, on lattice-work or rushes, and then piled up in heaps a yard high, in an airy place, but under cover, when they diminished in size and became hard. These balls, when of good quality, exhibited, on being broken, a light blue or sea-green colour. They are usually sold in this state to manufacturers, by whom they were subjected to a second process in order to render them fit for the use of the dyer. This process was conducted in the following manner:—The woad balls were first broken by means of wooden hammers, and the triturated mass was heaped up on a wooden floor, sprinkled with water, sometimes with a little wine, and allowed to ferment or putrefy. The mass became very hot, and emitted a strong ammoniacal odour, and much vapour. In order to regulate the process, it was frequently turned over with shovels, and again sprinkled with water. When the heat had subsided, the mass, which had become dry, was pounded, passed through sieves, and then packed in barrels ready for use. It had the appearance of pigeons' dung.

In France the paste obtained by pounding the woad-leaves was taken to a room with a sloping pavement, open at one end, laid in a heap at the higher end of the room, and allowed to ferment for a period of twenty or thirty days. The mass swelled up and often showed cracks or fissures, which were always carefully closed as soon as they appeared, whilst a black juice exuded and ran away in gutters constructed for the purpose. When the fermented heap had become moderately dry, it was ground again and formed into cakes, called in French *coques*, which were then fully dried, and in this state brought to market. In France and Italy a second fermentation was not generally thought essential, but when performed it was conducted exactly in the manner just described.

At the present day woad is nowhere employed alone for the purpose of dyeing blue, since it is found more economical to use indigo, and the cultivation of the plant has therefore declined considerably, and has even become nearly extinct in districts where it was formerly carried on extensively. By woollen dyers, however, it is still used, but only as a means of exciting fermentation, and thus reducing the indigo blue in their vats; indeed, the woad employed by them contains little or no blue colouring-matter. See INDIGO.

Numerous attempts have been made to extract the blue colouring-matter from woad, in the same way that indigo is extracted from the leaves of the *Indigofera* in the East Indies and other countries. At the commencement of the present century, when the price of indigo on the Continent of Europe was very high, a prize of 100,000 francs was even offered by the French Government for the discovery of a method of obtaining from the *Isatis tinctoria*, or some other native plant, a dyeing material, which, both in regard to price and the beauty and solidity of its colour, should form a perfect substitute for indigo. The experiments which were made in consequence served to prove that it was quite possible to obtain genuine indigo from woad-leaves, but that the process could never be carried on profitably on account of the very small proportion of colouring-matter contained in the plant. Nine parts of fresh leaves yield only one part of the prepared material or pastel, and the latter does not afford more than 2 per cent. of its weight of indigo. According to Chevreul, the leaves of the *Indigofera anil*, even when grown in the neighbourhood of Paris, contain 30 times as much indigo-blue as those of the *Isatis tinctoria*, and, when cultivated in tropical countries, the amount is probably still higher. The comparatively high price of land and labour would probably itself prove a sufficient obstacle to the successful manufacture of indigo in most European countries, even if the yield were equal to what it is in the tropics.

In 1808 Chevreul published the results of his analysis of woad and pastel. It has more recently been made the subject of chemical investigation, for the purpose of ascertaining the state in which indigo-blue exists in plants and other organisms. See INDIGO.—E. S.

WOOD-PRESERVING. The preservation of wood from decay depends upon the combination of the vegetable albumen with some metallic salt or some powerful antiseptic agent. Bethell's invention, which was much employed, consists in impregnating wood throughout with oil of tar and other bituminous matters containing creosote, and also with pyrolignite of iron, which holds more creosote in solution than any other watery menstruum.

The wood was put in a close iron tank, like a high-pressure steam-boiler, which was closed and filled with the tar oil or pyrolignite. The air being exhausted by air-pumps, afterwards more oil or pyrolignite was forced in by hydrostatic pumps, until a pressure equal to from 100 to 150 lbs. to the inch was obtained. This pressure was kept up by the frequent working of the pumps during six or seven hours, whereby the wood became thoroughly saturated with the tar oil, or the pyrolignite of iron, and weighed from 8 to 12 pounds per cube foot heavier than before.

In a large tank 20 loads of timber per day could be prepared. The atmospheric action on wood thus prepared renders it tougher, and infinitely stronger. A post made of beech, or even of Scotch fir, is rendered more durable, and as strong as one made of the best oak; the bituminous mixture with which all its pores are filled acting as a cement to bind the fibres together in a close tough mass; and the more porous the wood is, the more durable and tough it becomes, as it imbibes a greater quantity of the bituminous oil, which is proved by its increased weight. The materials which are injected preserve iron and metals from corrosion; and an iron bolt driven into wood so saturated remains perfectly sound and free from rust. It also resists the attack of insects.

The effect produced is that of perfectly coagulating the albumen in the sap, thus preventing its putrefaction. For wood that will be much exposed to the weather, and alternately wet and dry, the mere coagulation of the sap is not sufficient; for although the albumen contained in the sap of the wood is the most liable and the first to putrefy, yet the ligneous fibre itself, after it has been deprived of all sap, will, when exposed in a warm damp situation, rot and crumble into dust. To preserve wood, therefore, that will be much exposed to the weather, it is not only necessary that the sap should be coagulated, but that the fibres should be protected from moisture.

Wood prepared with petroleum for sleepers, piles, poles, fencing, &c., is not affected by alternate exposure to wet and dry; it requires no painting, and after it has been exposed to the air for some days it loses every unpleasant smell.

For railway sleepers it is highly useful, as the commonest Scotch-fir sleeper, when thus prepared, will last. Posts for gates or fencing, if prepared in this manner, may be made of Scotch fir. The processes which have been introduced for impregnating wood with the protosulphate of iron, corrosive sublimate, chloride of lime, and similar substances, are also much employed, and many of them have been found to be very useful as preservative agents. The tungstate of soda has been found to be a useful preservative of wood.

WOOF is the same as Weft.

WOOL. In reference to textile fabrics, sheep's wool is of two different sorts, the short- and the long-stapled; each of which requires different modes of manufacture in the preparation and spinning processes, as also in the treatment of the cloth after it is woven, to fit it for the market. Each of these is, moreover, distinguished in commerce by the names of 'fleece wools' and 'dead wools,' according as they have been shorn at the usual annual period from the living animal, or are cut from its skin after death. The latter are comparatively harsh, weak, and incapable of imbibing the dyeing principles, more especially if the sheep has died of some malignant distemper. The annular pores, leading into the tubular cavities of the filaments, seem, in this case to have shrunk and become obstructed. The time of year for sheep-shearing most favourable to the quality of the wool, and the comfort of the animal, is during the month of June—the period when Lord Leicester holds his celebrated rural fête for that interesting purpose.

The wool of the sheep has been surprisingly improved by its domestic culture. The *mouflon* (*Ovis aries*), the parent stock from which our sheep is undoubtedly derived, and which is still found in a wild state upon the mountains of Sardinia, Corsica, Barbary, Greece, and Asia Minor, has a very short and coarse fleece, more like hair than wool. When this animal is brought under the fostering care of man, the rank fibres gradually disappear; while the soft wool round their roots, little conspicuous in the wild animal, becomes singularly developed. The male most speedily undergoes this change, and continues ever afterwards to possess far more power in modifying the fleece of the offspring than the female parent. The produce of a breed from a coarse-woolled ewe and a fine-woolled ram, is not of a mean quality between the two, but half-way nearer that of the sire. By coupling the female thus generated with such a male as the former, another improvement of one-half will be obtained, affording a staple three-fourths finer than that of the grandam. By proceeding inversely, the wool would be as rapidly deteriorated. It is, therefore, a matter of the first consequence in wool husbandry, to exclude from the flock all coarse-fleeced rams.

Long wool is the produce of a peculiar variety of sheep, and varies in the length of its fibres from 3 to 8 inches. Such wool is not carded like cotton, but combed like flax, either by hand or appropriate machinery. Short wool is seldom longer than 3 or 4 inches; it is susceptible of carding and felting, by which processes the filaments become densely matted together. The shorter sorts of combing wool are used principally for hosiery, though of late years the finer kinds have been extensively worked up into merino and mousseline-de-laine fabrics. The longer wools of the Leicestershire breed are manufactured into hard yarns, for worsted-pieces, such as bombazines, poplins, crapes, orleans, &c.

The wool of which good broad-cloth is made should be not only shorter, but, generally speaking, finer and softer than the worsted wools, in order to fit them for the fulling process. Some wool-sorters and wool-staplers acquire by practice great nicety of discernment in judging of wools by the touch and traction of the fingers. The filaments of the finer qualities vary in thickness from $\frac{1}{1100}$ to $\frac{1}{1500}$ of an inch; their structure is very curious, exhibiting, in a good achromatic microscope, at intervals of about $\frac{1}{300}$ of an inch, a series of serrated rings, imbricated towards each other, like the joints of *Equisetum*, or rather like the scaly zones of a serpent's skin.

The fleece of an average English sheep contains five distinct long sorts and three short sorts. The short sorts grow on the belly of the sheep, the finest being under the neck and the fore-legs. Of the long sorts, the finest is on the shoulders. The next occupies a position almost semicircular round the finest sort, commencing at the head, and extending to the belly. The third sort adjoins the second, and is of a somewhat triangular shape, the base being on the top of the back. The fourth adjoins the third on one side, the other side of it being the fifth, which covers the rump, and runs down almost straight, 3 or 4 inches wide, to where the wool terminates on the hind-legs.

The harshness of wools is dependent not solely upon the breed of the animal, or the climate, but is owing to certain peculiarities in the pasture, derived from the soil. It is known, that in sheep fed upon chalky districts, wool is apt to get harsh; but in those upon a rich loamy soil, it becomes soft and silky. The ardent sun of Spain renders the fleece of the Merino breed harsher than it is in the milder climate of Saxony. The Angora, or Angola, or Angona wool, from Agnolia, 39° 53′ N. lat., 32° 52′ E. long., owes its beautiful character to the place of its growth. This wool is the same as *Mohair*. Smearing sheep with a mixture of tar and butter is deemed, in cold countries, favourable to the softness of their wool.

All wool, in its natural state, contains a quantity of a peculiar potash-soap, secreted by the animal, called in this country the *yolk*; which may be washed out by water alone, with which it forms a sort of lather. It constitutes from 25 to 50 per cent. of the wool, being most abundant in the Merino breed of sheep; and, however favourable to the growth of the wool on the living animal, should be taken out before or soon after it is shorn, lest it injure the fibres by fermentation, and cause them to become hard and brittle. After being washed in water, somewhat more than lukewarm, the wool should be well pressed, and carefully dried. See Suint.

Mr. Hicks, of Huddersfield, obtained a patent some years ago for a machine for cleaning wool from burs. It consists of 4 rotatory beaters, which act in succession. The wool having been opened and spread upon a feeding-cloth, is carried by it to the drawing-rollers, and is then delivered to the action of the beater, by which it is carried along a curved grating to the feed-cloth of another beater, so as to be made eventually quite clean.

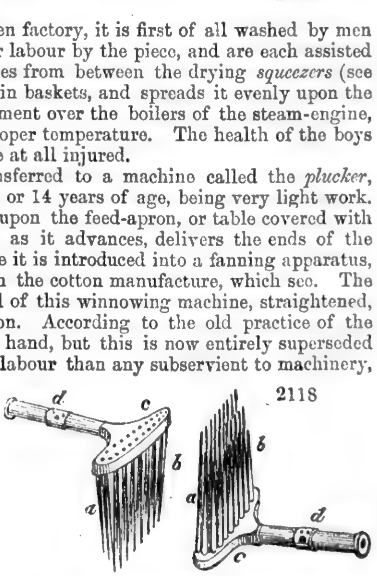
WOOL DYEING. See Dyeing.

WOOLLEN MANUFACTURE. In this branch of business, a short-stapled soft wool is required capable of being milled or felted, so that in the after-processes a finer finish may be brought upon the cloth.

When the wool is brought into the woollen factory, it is first of all washed by men with soap-and-water, who are paid for their labour by the piece, and are each assisted by a boy, who receives the wool as it issues from between the drying *squeezers* (see Bleaching). The boy carries off the wool in baskets, and spreads it evenly upon the floor of the drying-room, usually an apartment over the boilers of the steam-engine, which is thus economically heated to the proper temperature. The health of the boys employed in this business is not found to be at all injured.

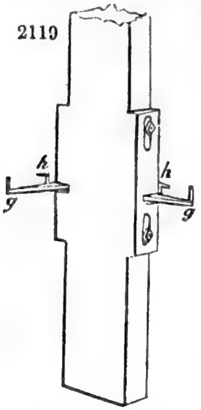
The wool, when properly dried, is transferred to a machine called the *plucker*, which is always superintended by a boy 12 or 14 years of age, being very light work. He lays the tresses of wool pretty evenly upon the feed-apron, or table covered with an endless moving web of canvas, which, as it advances, delivers the ends of the long tufts to a pair of fluted rollers, whence it is introduced into a fanning apparatus, somewhat similar to the *willow* employed in the cotton manufacture, which see. The filaments are turned out at the opposite end of this winnowing machine, straightened, cleaned, and ready for the combing operation. According to the old practice of the trade, the wool was carded and combed by hand, but this is now entirely superseded by machinery. This was far more severe labour than any subservient to machinery, and was carried on in rooms rendered close and hot by the number of stoves requisite to heat the combs, and so enable them to render the fibres soft, flexible, and elastic. This was a task at which only robust men were engaged. They use three implements: 1, a pair of combs for each person; 2, a post, to which one of the combs can be fixed; 3, a comb-pot or small stove for heating the teeth of the combs. Each comb is composed either of two or three rows of pointed tapering steel teeth, *b*, *fig.* 2118, disposed in two or three parallel planes, each row being a little longer than the preceding. They are made fast at the roots to a wooden stock or head *c*, which is covered with horn and has a handle *d*, fixed into it at right angles to the lines of the teeth. The spaces between these two or three planes of teeth is about one-third of an inch at their bottoms, but somewhat more at their tips. The first combing, when the fibres are most entangled, is performed with

2118



the two-row toothed combs; the second or finishing combing, with the three-row toothed.

2119



In the workshops a post, *fig.* 2119, is planted upright, for resting the combs occasionally upon, during the operation. An iron stem *g*, projects from it horizontally, having its end turned up, so as to pass through a hole in the handle of the comb. Near its point of insertion into the post, there is another staple point, *h*, which enters into the hollow end of the handle; which, between these two catches, is firmly secured to the post. The stove is a very simple affair, consisting merely of a flat iron plate, heated by fire or steam, and surmounted with a similar plate, at an interval sufficient to allow the teeth to be inserted between them at one side, which is left open, while the space between their edges, on the other side, is closed to confine the heat.

In combing the wool, the workman takes it up in tresses of about four ounces each, sprinkles it with oil, and rolls it about in his hands, to render all the filaments equally unctuous. Some harsh dry wools require one-sixteenth of their weight of oil, others no more than a fortieth. He next attaches a heated comb to the post, with its teeth pointed upwards, seizes one-half the tress of wool in his hands, throws it over the teeth, then draws it through them, and thus repeatedly: leaving a few straight filaments each time upon the comb. When the comb has in this way collected all the wool, it is placed with its points inserted into the cell of the stove, with the wool hanging down outside, exposed to the influence of the heat. The other comb, just removed in a heated state from the stove, is planted upon the post, and furnished in its turn with the remaining two-ounce tress of wool; after which it supplants the preceding at the stove. Having both combs now hot, he holds one of them with his left hand over his knee, being seated upon a low stool, and seizing the other with his right hand, he combs the wool upon the first, by introducing the teeth of one comb into the wool stuck in the other, and drawing them through it. This manipulation is skilfully repeated, till the fibres are laid truly parallel like a flat tress of hair. It is proper to begin by combing the tips of the tress, and to advance progressively, from the one end towards the other, till at length the combs are worked with their teeth as closely together as is possible, without bringing them into collision. If the workman proceeded otherwise, he would be apt to rupture the filaments, or tear their ends entirely out of one of the combs. The flocks left at the end of the process, because they are too short for the comber to grasp them in his hand, are called *noyls*. They are unfit for the worsted spinner, and are reserved for the coarse cloth manufacturer.

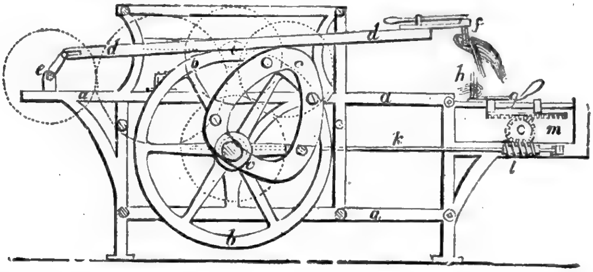
The wool finally drawn off from the comb, though it may form a uniform tress of straight filaments, must yet be combed again at a somewhat lower temperature, to prepare it perfectly for the spinning operation. From ten to twelve slivers are then arranged in one parcel.

To relieve the workman from this laborious and not very salubrious task has been the object of many mechanical inventions. One of these, considerably employed in this country and in France, is the invention of the late Mr. John Collier, of Paris, for which a patent was obtained in England, under the name of John Platt, of Salford, in November 1827. It consists of two comb-wheels about ten feet in diameter, having hollow iron spokes filled with steam, in order to keep the whole apparatus at a proper combing heat. The comb forms a circle, made fast to the periphery of the wheel, the teeth being at right angles to the plane of the wheel. The shafts of the two wheels are mounted in a strong frame of cast iron; not, however, in horizontal positions, but inclined at acute angles to the horizon, and in planes crossing each other, so that the teeth of one circular comb sweep with a steady obliquity over the teeth of the other, in a most ingenious manner, with the effect of combing the tresses of wool hung upon them. The proper quantity of long wool, in its ordinary state, is stuck in handfuls upon the wheel, revolving slowly, by a boy, seated upon the ground at one side of the machine. Whenever the wheel is dressed, the machine is made to revolve more rapidly, by shifting its driving-band on another pulley; and it is beautiful to observe the delicacy and precision with which it smooths the tangled tress. When the wools are set in rapid rotation, the loose ends of the fleece, by the centrifugal force, are thrown out, in the direction of radii, upon the teeth of the other revolving comb-wheel, so as to be drawn out and made truly straight. The operation commences upon the tips of the tresses, where the wheels, by the oblique posture of their shafts, are at the greatest distance apart; but as the planes slowly approach to parallelism, the teeth enter more deeply into the wool, till they progressively comb the whole length of its fibres. The machine being then thrown out of gear, the teeth are stripped of the tresses by the hand of the attendant; the *noyls*, or short refuse wool, being also removed, and kept by itself.

This operation being one of simple superintendence, not of handicraft effort and skill, like the old combing of long wool, is now performed by boys or girls of 13 and 14 years of age; and places in a striking point of view the influence of automatic mechanism, in so embodying dexterity and intelligence in a machine, as to render the cheap and tractable labour of children a substitute for the high-priced and often refractory exertions of workmen too prone to capricious combinations. The chief precaution to be taken with this machine, is to keep the steam-joints tight, so as not to wet the apartments, and provide due ventilation for the operatives.

The machine patented by James Noble, of Halifax, worsted-spinner, deserves particular notice, as its mode of operation adapts it well also for heckling flax. In *fig*. 2120, its internal structure is exhibited. The framework, *a*, *a*, supports the axle of a wheel, *b*, *b*, in suitable bearings on each side. To the face of this wheel is affixed the excentric or heart-wheel cam, *c*, *c*. On the upper part of the periphery of this cam or heart-wheel, a lever, *d*, *d*, bears merely by its gravity; one end of which lever is connected by a joint to the crank, *e*. By the rotation of the crank, *e*, it will be perceived that the lever *d*, will be slidden to and fro on the upper part of the periphery of the excentric or heart-wheel cam, *c*, the outer end of the lever, *d*, carrying the upper or working comb or needle-points, *f*, as it moves, performing an elliptical curve, which curve will be dependent upon the position of the heart-wheel cam, *c*, that guides it. A moveable frame, *g*, carries a series of points, *h*, which are to constitute the lower comb or frame of needles. Into these lower needles the rough uncombed wool is to be fed by hand, and to be drawn out and combed straight by the movements of the upper or working comb.

2120



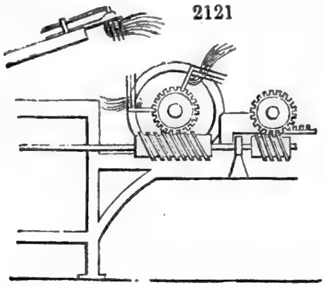
As it is important, in order to prevent waste, that the ends of the wool should be first combed out, and that the needle-points should be made to penetrate the wool progressively, the moveable frame, *g*, is in the first instance placed as far back as possible; and the action of the lever, *d*, during the whole operation, is so directed by the varying positions of the cam-wheel, as to allow the upper comb to enter at first a very little way only into the wool; but as the operation of combing goes on, the frame with the lower combs is made to advance gradually, and the relative positions of the revolving heart cam-wheel *c*, being also gradually changed, the upper or working needles are at length allowed to be drawn completely through the wool, for the purpose of combing out straight the whole length of its fibre.

In order to give the machine the necessary movements, a train of toothed wheels and pinions is mounted, mostly on studs attached to the side of the frame; which train of wheels and pinions is shown by dots in the figure, to avoid confusion. The driving power, a horse or steam-engine, is communicated by a band to a rigger on the short axle *i*; which axle carries a pinion, taking into one of the wheels of the train. From this wheel the crank *e*, that works the lever *d*, is driven; and also, by gear from the same pinion, the axle of the wheel *b*, carrying the excentric or heart-wheel cam, is also actuated, but slower than the crank-axle.

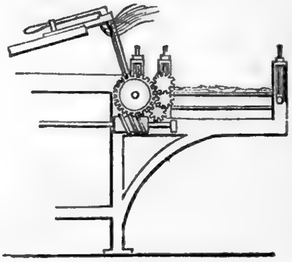
At the end of the axle of the wheel *b*, and cam *c*, a bevel-pinion is affixed, which gears into a corresponding bevel-pinion on the end of the lateral shaft *k*. The reverse end of this shaft has a worm or endless screw *l*, taking into a toothed-wheel *m*; and this last-mentioned toothed-wheel gears into the rack at the under part of the frame *g*.

It will hence be perceived, that by the movements of the train of wheels, a slow motion is given to the frame *g*, by which the lower needles carrying the wool are progressively advanced as the operation goes on; and also, that by the other wheels of the train, the heart-wheel cam is made to rotate, for the purpose of giving such varying directions to the stroke of the lever which slides upon its periphery, and to the working comb, as shall cause the comb to operate gradually upon the wool as it is brought forward. The construction of the frames which hold the needles, and the manner of fixing them in the machine, present no features of importance; it is therefore unnecessary to describe them further, than to say, that the heckles are to be heated when used for combing wool. Instead of introducing the wool to be combed into the lower needles by hand, it is sometimes fed in, by means of an endless feeding-cloth, as shown in *fig.* 2121. This endless cloth is distended over two rollers, which are made to revolve, for the purpose of carrying the cloth with the wool forward, by means of the endless screw and pinions.

2121



2122



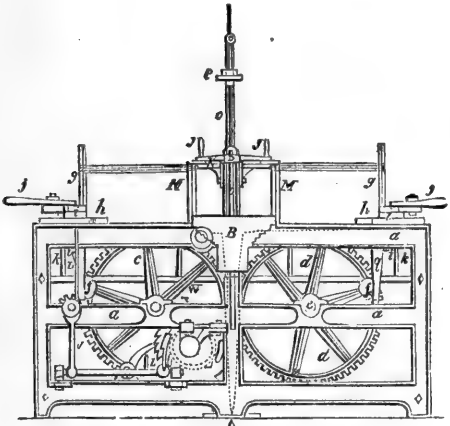
A slight variation in the machine is shown at *fig.* 2122, for the purpose of combing wool of long fibre, which differs from the former only in placing the combs or needle-points upon a revolving cylinder or shaft. At the end of the axle of this shaft, there is a toothed wheel, which is actuated by an endless screw upon a lateral shaft. The axle of the cylinder on which the needles are fixed, is mounted in a moveable frame or carriage, in order that the points of the needles may, in the first instance, be brought to act upon the ends of the wool only, and ultimately be so advanced as to enable the whole length of the fibres to be drawn through. The progressive advancement of this carriage, with the needle-cylinder, is effected by the agency of the endless screw on the lateral shaft before mentioned.

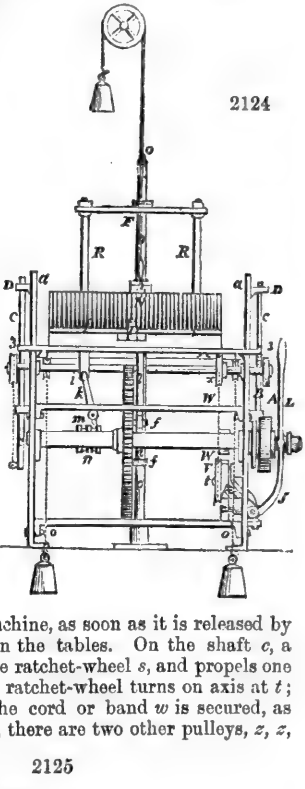
Some combing-machines reduce the wool into a continuous sliver, which is ready for the drawing-frame; but the short slivers produced by the hand-combing, must be first joined together, by what is called *planking*. These slivers are rolled up by the combers ten or twelve together, in balls called 'tops,' each of which weighs a half pound. At the spinning-mill these are unrolled, and the slivers are laid on a long plank or trough, with the ends lapping over, in order to splice the long end of one sliver into the short end of another. The long end is that which was drawn off first from the comb, and contains the longer fibres; the short is that which comes last from the comb, and contains the shorter. The wool-comber lays all the slivers of each ball the same way, and marks the long end of each by twisting up the end of the sliver. It is a curious circumstance, that when a top or ball of slivers is unrolled and stretched out straight, they will not separate from each other without tearing and breaking, if the separation is begun at the short ends; but if they are first parted at the long ends they will readily separate.

The machine for combing long wool, for which Messrs. Donisthorpe and Rawson obtained a patent in April 1835, has been found to work well, and therefore merits a detailed description.

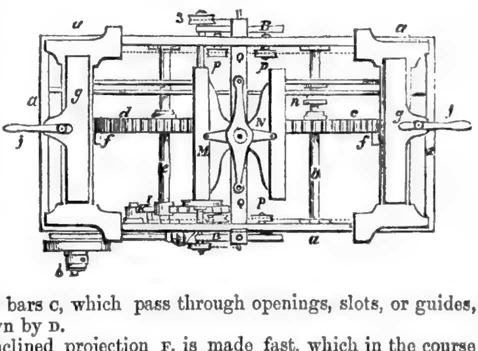
Fig. 2123 is an elevation, *fig.* 2124 an end view, and *fig.* 2125 a plan, in which *a*, *a*, is the framing; *b*, the main shaft, bearing a pinion, which drives the wheel and shaft *c*, in gear with the wheel *d*, on the shaft *e*. Upon each of the wheels *c* and *d*, there are two projections or studs *f*, which cause the action of the combs *g*, *g*, of which *h*, *h*, are the tables or carriages. These are capable of sliding along the upper guide-rails of the framing *a*. Through these carriages or tables *h*, *h*, there are openings or slits, shown by dotted lines, which act as guides to the holders *i*, *i*, of the combs *g*, *g*, rendering the holders susceptible of motion at right angles to the course pursued by the tables *h*. The combs are retained in the holders *i*, *i*, by means of the lever-handles *j*, *j*, which move upon inclined surfaces, and are made to press on the surface of the heads of the combs *g*, *g*, so as to be retained in their places; and they are also held by studs affixed to the holders, which pass into the comb-heads. From the under side of the tables, forked projections *i*, *i*, stand out, which pass through the openings or slits formed in the tables *h*, *h*; these projections are worked from side to side by the frame *k*, *k*, which turning on the axis or shaft *l*, *l*, is caused to vibrate, or rock to and fro, by the arms *m*, moved by the excentric groove *n*, made fast to the shaft *e*. The tables *h*, are drawn inwards, by weights suspended on cords or straps *o*, *o*, which pass over friction pulleys *p*, *p*; whereby the weights have a constant tendency to draw the combs into the centre of the machine, as soon as it is released by the studs *f*, passing beyond the projecting arms *g*, on the tables. On the shaft *c*, a driving-tooth or catch *r*, is fixed, which takes into the ratchet-wheel *s*, and propels one of its teeth at every revolution of the shaft *c*. This ratchet-wheel turns on axis at *t*; to the ratchet the pulley *v* is made fast, to which the cord or band *w* is secured, as also to the pulley *x*, on the shaft *y*. On the shaft *y*, there are two other pulleys, *z*, *z*, having the cords or bands A, A, made fast to them, and also to the end of the gauge-plates B, furnished with graduated steps, against which the tables *h*, *h*, are drawing at each operation of the machine. In proportion as these gauge-plates are raised, the nearer the carriages or tables *h* will be able to advance to the centre of the machine, and thus permit the combs *g*, *g*, to lay hold of, and comb, additional lengths of the woolly fibres. The gauge-plates B, are guided up by the bars C, which pass through openings, slots, or guides, made in the framing *a*, as shown by D.

2124





2125

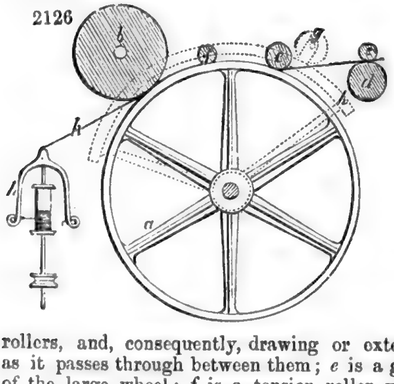


To the ratchet-wheel *s*, an inclined projection F, is made fast, which in the course of the rotation of the ratchet-wheel, comes under the lever F, fixed to the shaft G, that turns in bearings H. To this shaft the levers I and J, are also affixed; I serving to throw out the click or catch K, from the ratchet-wheel, by which the parts of the machine will be released, and restored to positions ready for starting again. The lever J, serves to slide the drum upon the driving shaft *b*, out of gear, by means of the forked handle L, when the machine is to be stopped, whenever it has finished combing a certain quantity of wool. The combs which hold the wool have a motion upwards, in order to take the wool out of the way of the combs *g*, *g*, as these are drawn into the centre of the machine; while the holding combs descend to lay the wool among the points of the combs *g*, *g*. For obtaining this upward-and-downward motion, the combs M, M, are placed between the frame N, and retained there just as the combs *g*, *g*, are upon the holders *i*, *i*. The framing N, is made fast to the bar or spindle O, which moves vertically through openings in the cross-head P, and the cross-framing of the machine Q; from the top of which there is a strap passing over pulleys with a suspended weight to it; the cross-head being supported by the two guide-rods R, fixed to the cross-framing Q. It is by the guide-rods R, and the spindle O, that the frame N is made to move up and down; while the spindle is made to rise by the studs *f*, as the wheels *c* and *d* come successively under the studs *s*, on the spindle O.

A quantity of wool is to be placed on each of the combs *g*, *g*, and M, M, the machine being in the position shown in *fig.* 2125. When the main-shaft *b*, is set in motion, it will drive by its pinion the toothed wheel *c*, and therefrom the remaining parts of the machine. The first effect of the movement will be to raise the combs M, M, sufficiently high to remove the wool out of the way of the combs *g*, *g*, which will be drawn towards the centre of the machine, as soon as they are released by the studs *f*, passing the projecting arms *q*, on the tables *h*; but the distance between the combs *g*, *g*, and the combs M, M, will depend on the height to which the gauge-plates B have been raised. These plates are raised one step at each revolution of the shaft *c*; the combs *g*, *g*, will therefore be continually approaching more nearly to the combs M, M, till the plates B, are so much raised as to permit the tables *h* to approach the plates B, below the lowest step or graduation, when the machine will continue to work. Notwithstanding the plates B continuing to rise, there being only parallel surfaces against which the tables come, the combs *g*, *g*, will successively come to the same position, till the inclined projection E, on the ratchet-wheel *s*, comes under the lever F, which will stop the machine. The wool which has been combed, is then to be removed, and a fresh quantity introduced. It should be remarked that the combs *g*, *g*, are continually moving from side to side of the machine, at the same time that they are combing out the wool. The chief object of the invention is obviously to give the above peculiar motion to the combs *g*, *g*, and M, M, which may be applied also to combing goat-hair.

For the purposes of the worsted manufacture, wool should be rendered inelastic to a considerable degree, so that its fibres may form long lines, capable of being twisted into straight level yarn. Mr. Bayliffe, of Kendal, has sought to accomplish this object, first, by introducing into the *drawing* machine a rapidly revolving wheel, in contact with the front drawing roller, by whose friction the filaments are heated, and at the same time deprived of their curling elasticity; secondly, by employing a moveable regulating roller, by which the extent of surface on the periphery of the wheel that the lengths of wool is to act upon, may be increased or diminished at pleasure, and, consequently, the effect regulated or tempered as the quality of the wool may require; thirdly, the employment of steam in a rotatory drum or hollow wheel, in place of the wheel first described, for the purpose of heating the wool, in the process of drawing, in order to facilitate the operation of straightening the fibres.

2126



These objects may be effected in several ways; that is, the machinery may be variously constructed, and still embrace the principles proposed. *Fig.* 2126, shows one mode:—*a*, is the friction wheel; *b*, the front drawing roller, placed in the drawing-frame in the same way as usual; the larger wheel *a*, constituting the lower roller of the pair of front drawing rollers; *c* and *d* are the pair of back drawing rollers, which are actuated by gear connected to the front rollers, as in the ordinary construction of drawing machines, the front rollers moving very considerably faster than the back rollers, and, consequently, drawing or extending the fibres of the sliver of wool, as it passes through between them; *e* is a guide-roller, bearing upon the periphery of the large wheel; *f* is a tension roller, which presses the fibres of the wool down upon the wheel *a*.

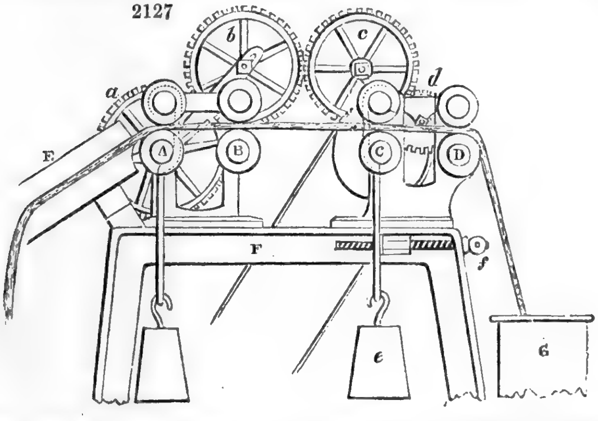
Now, supposing the back rollers *c* and *d*, to be turned with a given velocity, and the front roller *b* to be driven much faster, the effect would be, that the fibres of wool constituting the sliver, passing through the machine, would be considerably extended between *b* and *d*, which is precisely the effect accomplished in the ordinary drawing frame; but the wheel *a*, introduced into the machine in place of the lower front drawing roller, being made to revolve much faster than *b*, the sliver of wool extended over the upper part of its periphery from *b*, to the tension roller *f*, will be subjected to very considerable friction from the contact; and, consequently, the natural curl of the wool will be taken out, and its elasticity destroyed, which will enable the wool to proceed in a connected roving down to the spindle or flyer *h*, where it becomes twisted or spun into a worsted thread.

In order to increase or diminish the extent to which the fibres of wool are spread over the periphery of the wheel *a*, a regulating roller is adapted to the machine, as shown at *g*, in place of the tension roller *f*. This regulating roller *g*, is mounted by its pivots in bearings on the circular arms *h*, shown by dots. These circular arms turn loosely upon the axle of the wheel *a*, and are raised or depressed by a rack and a winch, not shown in the figure; the rack taking into teeth on the periphery of the circular arms. It will hence be perceived, that by raising the circular arms, the roller *g*, will be carried backward, and the fibres of wool pressed upon the periphery of the wheel to a greater extent. On the contrary, the depression of the circular arms will draw the roller *g*, forward, and cause the wool to be acted upon by a smaller portion of the periphery of the wheel *a*, and consequently subject it to less friction.

When it is desired to employ steam for the purpose of heating wool, the wheel *a*, is formed as a hollow drum, and steam from a boiler, in any convenient situation, is conveyed through the hollow axle to the interior of the drum, which, becoming heated by that means, communicates heat also to the wool, and thereby destroys its curl and elasticity.

Breaking-frame.—Here the slivers are *planked*, or spliced together, the long end of one to the short end of another; after which they are drawn out and extended by the rollers of the breaking-frame. A sketch of this machine is given in *fig.* 2127. It consists of four pairs of rollers A, B, C, D. The first pair A, receives the wool from the inclined trough E, which is the planking-table. The slivers are unrolled, parted, and hung loosely over a pin, in reach of the attendant, who takes a sliver, and lays it flat in the trough, and the end is presented to the rollers A, which being in motion, will draw the wool in; the sliver is then conducted through the other rollers, as shown in the figure: when the sliver has passed half through, the end of another sliver is placed upon the middle of the first, and they pass through together; when this second is passed half through, the end of a third is applied upon the middle of it, and in this way the short slivers produced by the combing are joined into one regular and even sliver.

2127



The lower roller C, receives its motion from the mill, by means of a pulley upon the end of its axis, and an endless strap. The roller which is immediately over it, is borne down by a heavy weight, suspended from hooks, which are over the pivots of the upper roller. The fourth pair of rollers D, moves with the same velocity as C, being turned by means of a small wheel upon the end of the axis of the roller C, which turns a wheel of the same size upon the axis of the roller D, by means of an intermediate wheel *d*, which makes both rollers turn the same way round. The first and second pair of rollers, A and B, move only one-third as quick as C and D, in order to draw out the sliver between B and C, to three times the length it was when put on the planking-table. The slow motion of the rollers A, is given by a large wheel *a*, fixed upon the axis of the roller A, and turned by the intermediate cog-wheels *b*, *c*, and *d*; the latter communicates between the rollers C and D. The pinions on the rollers C and D, being only one-third the size of the wheel *a*, C and D turn three times as fast as A, for *b*, *c*, and *d* are only intermediate wheels. The rollers B turn at the same rate as A. The upper roller C is loaded with a heavy weight, similar to the rollers A; but the other rollers, B and D, are no further loaded than the weight of the rollers.

The two pairs of rollers A, B, and C, D, are mounted in separate frames; and that frame which contains the third and fourth pairs C, D, slides upon the cast-iron frame F, which supports the machine, in order to increase or diminish the distance between the rollers B and C. There is a screw *f*, by which the frame of the rollers is moved, so as to adjust the machine according to the length of the fibre of the wool. The space between B and C should be rather more than the length of the fibres of the wool. The intermediate wheels *b* and *c* are supported upon pieces of iron, which are moveable on centres; the centre for the piece which supports the wheel *b* is concentric with the axis of the roller A; and the supporting piece for the wheel *c* is fitted on the centre of the wheel *d*. By moving these pieces the intermediate wheels *b* and *c* can be always kept in contact, although the distance between the rollers is varied at times. By means of this breaking-frame, the perpetual sliver, which is made up by planking the sliver together, is equalised, and drawn out three times in length, and delivered into the can G.

Drawing-frame.—Three of these cans are removed to the drawing-frame, which is similar to the breaking-frame, except that there is no planking-table E. There are five sets of rollers, all fixed upon one common frame F, the breaking-frame, which we have described, being the first. As fast as the sliver comes through one set of rollers it is received into a can, and then three of these cans are put together and passed again through another set of rollers. In the whole the wool must pass through the breaker and four drawing-frames before the roving is begun. The draught being usually four times at each operation of drawing, and three times in the breaking, the whole will be $3 \times 4 \times 4 \times 4 \times 4 = 768$; but to suit different sorts of wool the three last drawing-frames are capable of making a greater draught, even to five times, by changing the pinions; accordingly the draught will be $3 \times 4 \times 5 \times 5 \times 5 = 1500$ times.

The size of the sliver is diminished by these repeated drawings, because only three slivers are put together, and they are drawn out four times; so that in the whole the sliver is reduced to a fourth or a ninth of its original bulk.

The breaking-frame and drawing-frame which are used when the slivers are prepared by the combing-machines, are differently constructed; they have no planking-table, but receive three of the perpetual slivers of the combing-machine from as many tin cans, and draw them out from ten to twelve times. In this case all the four rollers contribute to the operation of drawing: thus the second rollers B move 2½ times as fast as the rollers A; the third rollers C move 8 times as fast as A; and the fourth rollers E move 10½ times as fast as A. In this case the motion is given to the different rollers by means of bevelled wheels, and a horizontal axis, which extends across the ends of all the four rollers, to communicate motion from one pair of rollers to another.

There are three of these systems of rollers, which are all mounted on the same frame; and the first one through which the wool passes is called the 'breaking-frame'; but it does not differ from the others, which are called 'drawing-frames.' The slivers which have passed through one system of rollers are collected four or five together, and put through the drawing-rollers. In all the slivers pass through three drawings, and the whole extension is seldom less than 1,000 times, and for some kinds of wool much greater.

After the drawing of the slivers is finished, a pound weight is taken, and is measured by means of a cylinder, in order to ascertain if the drawing has been properly conducted; if the sliver does not prove of the length proposed, according to the size of worsted which is intended to be spun, the pinions of some of the drawing-frames are changed, to make the draught more or less, until it is found by experiment that one pound of the sliver measures the required length.

Roving-frame.—This is provided with rollers, the same as the drawing-frames: it takes in one or two slivers together, and draws them out four times. By this extension the sliver becomes so small that it would break with the slightest force, and it is therefore necessary to give some twist; this is done by a spindle and flyer. See *Roving*, under COTTON SPINNING.

Spinning-frame.—This is so much like the roving-frame that a short description will be sufficient. The spindles are more delicate, and there are three pairs of rollers, instead of two; the bobbins, which are taken off from the spindles of the roving-frame when they are quite full, are stuck upon skewers, and the roving which proceeds from them is conducted between the rollers. The back pair turns round slowly; the middle pair turns about twice for once of the back rollers; and the front pair makes from twelve to seventeen turns for one turn of the back roller, according to the degree of extension which is required.

The spindles must revolve very quickly in the spinning-frame, in order to give the requisite degree of twist to the worsted. The hardest twisted worsted is called 'tammy warp'; and when the size of this worsted is such as to be 20 or 24 hanks to the pound weight, the twist is about 10 turns in each inch of length. The least twist is given to the worsted for fine hosiery, which is from 18 to 24 hanks to the pound. The twist is from 5 to 6 turns per inch. The degree of twist is regulated by the size of the whirls or pulleys upon the spindle, and by the wheel-work which communicates the motion to the front rollers from the band-wheel, which turns the spindles.

It is needless to enter more minutely into the description of the spinning machinery, because the fluted roller construction, invented by Sir Richard Arkwright, fully described under COTTON SPINNING, is equally applicable to worsted. The difference between the two is chiefly in the distance between the rollers, which in the worsted-frame is capable of being increased or diminished at pleasure, according to the length of the fibres of the wool; and the draught or extension of the roving is far greater than in the cotton.

Reeling.—The bobbins of the spinning-frame are placed in a row upon wires before a long horizontal reel, and the threads from 20 bobbins are wound off together. The reel is exactly a yard in circumference, and when it has wound off 80 turns it rings a bell; the motion of the reel is then stopped, and a thread is passed round the 80 turns of folds which each thread has made. The reeling is then continued till another 80 yards is wound off, which is also separated by interweaving the same thread; each of these separate parcels is called 'a ley,' and when 7 such leys are reeled it is called 'a hank,' which contains 560 yards. When this quantity is reeled off, the ends of the binding thread are tied together, to bind each hank fast, and one of the rails of the reel is struck to loosen the hanks, and they are drawn off at the end of the reel. These hanks are next hung upon a hook, and twisted up hard by a stick; then doubled, and the two parts twisted together to make a firm bundle. In this state the hanks are weighed by a small index-machine, which denotes what number of the hanks will weigh a pound. And they are sorted accordingly into different parcels. It is by this means that the number of the worsted is ascertained as the denomination for its fineness: thus No. 24 means that 24 hanks each containing 560 yards will weigh a pound, and so on.

This denomination is different from that used for cotton, because the hank of cotton contains 840 yards instead of 560; but in some places the worsted hank is made of the same length as the cotton.

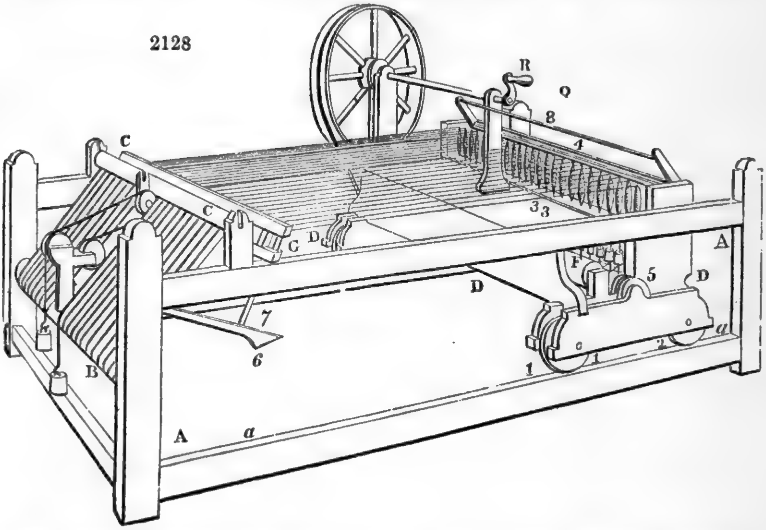
To pack up the worsted for market, the proper number of hanks is collected to make a pound, according to the number which has been ascertained; these are weighed as a proof of the correctness of the sorting, then tied up in bundles of one pound each, and four of these bundles are again tied together. Then 60 such bundles are packed up in a sheet, making a bale of 240 lbs. ready for market.

Of the treatment of short wool for the cloth manufacture.—Short wool resembles cotton not a little in the structure of its filaments, and is cleaned by the *willy*, as cotton is by the *willow*, which opens up the matted fleece of the wool-stapler, and cleans it from accidental impurities. Sheep's wool for working into coarse goods must be passed repeatedly through this machine, both before and after it is dyed; the second last time for the purpose of blending the different sorts together, and the last for imbuing the fibres intimately with oil. The oiled wool is next subjected to a first carding operation called *scribbling*, whereby it is converted into a broad thin fleece or lap, as cotton is by the breaker-cards of a cotton-mill. The woollen lap is then worked by the cards proper, which deliver it in a narrow band or sliver. By this process the wool expands greatly in all its dimensions; while the broken or short filaments get entangled by crossing in every possible direction, which prepares them for the fulling operation. See *Carding*, under COTTON SPINNING.

The *slubbing machine*, or *billy*, reduces the separate rolls of *cardings* into a continuous slightly-twisted spongy cord, which is sometimes called a roving. *Fig.* 2128 is a perspective representation of the slubbing machine in most common use. A, A, is the wooden frame; within which is the moveable carriage D, D, which runs upon the lower side rails at *a*, *a*, on friction wheels at 1, 2, to make it move easily backwards and forwards from one end of the frame to the other. The carriage contains a series of steel spindles, marked 3, 3, which receive rapid rotation from a long tin drum F, by means of a series of cords passing round the pulley or whorl of each spindle. This drum, 6 inches in diameter, is covered with paper, and extends across the whole breadth of the carriage. The spindles are set nearly upright in a frame, and about 4 inches apart; their under ends being pointed conically, turn in brass sockets, called 'steps,' and are retained in their position by a small brass collet, which embraces each spindle at about the middle of its length. The upper half of each spindle projects above the top of the frame. The drum revolves horizontally before the spindles, having its axis a little below the line of the whorls; and receives motion, by a pulley at one of its ends, from an endless band which passes round a wheel E, like the large domestic wheel formerly used in spinning wool by hand, and of similar dimensions. This wheel is placed upon the outside of the main frame of the machine, and has its shafts supported by upright standards upon the carriage D. It is turned by the spinner placed at Q, with his right hand applied to a winch R, which gives motion to the drum, and thereby causes the spindles to revolve with great velocity.

Each spindle receives a soft cylinder or carding of wool, which comes through beneath a wooden roller C, C, at the one end of the frame. This is the *billy roller*, so much talked of in the controversies between the operatives and masters in the cotton-factories, as an instrument of cruel punishment to children, though no such machine has been used in cotton-mills for half a century at least. These wooden rolls proceed to the series of spindles, standing in the carriage, in nearly a horizontal plane. By the alternate advance and retreat of the carriage upon its railway, the spindles are made to approach to, and recede from, the roller C, with the effect of drawing out a given length of the soft cord, with any desired degree of twist, in the following manner:—

2128



The carding-rolls are laid down straight, side by side, upon the endless cloth, strained in an inclined direction between two rollers, one of which is seen at B, and the other lies behind C. One carding is allotted to a spindle; the total number of each in one machine being from 50 to 100. The roller C, of light wood, presses gently with its weight upon the cardings, while they move onwards over the endless cloth, with the running-out of the spindle carriage. Immediately in front of the said roller, there is a horizontal wooden rail or bar G, with another beneath it, placed across the frame. The carding is conducted through between these two bars, the moveable upper one being raised to let any aliquot portion of the roll pass freely. When this bar is again let down, it pinches the spongy carding fast; whence this mechanism is called the 'clasp.' It is in fact the *clove*, originally used by Hargreaves in his cotton-jenny. The moveable upper rail G, is guided between sliders, and a wire 7, descends from it to a lever C. When the spindle carriage D, D, is wheeled close home to the billy roller, a wheel 5, lifts the end 6 of the lever, which, by the wire 7, raises the upper bar or rail G, so as to open the clasp, and release all the card-rolls. Should the carriage be now drawn a little way from the clasp bars, it would tend to pull a corresponding length of the cardings forward from the inclined plane B, C. There is a small catch, which lays hold of the upper bar of the clasp G, and hinders it from falling till the carriage has receded to a certain distance, and has thereby allowed from 7 to 8 inches of the cardings to be taken out. A stop upon the carriage then comes against the catch, and withdraws it; thus allowing the upper rail to fall and pinch the carding, while the carriage, continuing to recede, draws out or stretches that portion of the roll which is between the clasp and the spindle-points. But during this time the wheel has been turned to keep the spindles revolving, communicating the proper degree of twist to the cardings in proportion to their extension, so as to prevent them from breaking.

It might be imagined that the slubbing cords would be apt to coil round the spindles; but as they proceed in a somewhat inclined direction to the clasp, they receive merely a twisting motion, continually slipping over the points of the spindles, without getting wound upon them. Whenever the operative or slubber has given a due degree of twist to the rovings, he sets about winding them upon the spindles into a conical shape, for which purpose he presses down the faller-wire 8, with his left hand, so as to bear it down from the points of the spindles, and place it opposite to their middle part. He next makes the spindles revolve, while he pushes in the carriage slowly, so as to coil the slubbing upon the spindle into a conical cop. The wire 8, regulates the winding-on of the whole series of slubbings at once, and receives its proper angle of depression for this purpose from the horizontal rail 4, which turns upon pivots in its ends, in brasses fixed on the standards, which rise from the carriage D. By turning this rail on its pivots, the wire 8 may be raised or lowered in any degree. The slubber seizes the rail 4 in his left hand, to draw the carriage out; but in returning it, he depresses the faller-wire, at the same time that he pushes the carriage before him.

The cardings are so exceedingly tender, that they would readily draw out, or even break, if they were dragged with friction upon the endless cloth of the inclined plane. To save this injurious traction, a contrivance is introduced for moving the apron. A cord is applied round the groove in the middle part of the upper roller, and after passing over pulleys, as shown in the figure, it has a heavy weight hung at the one end, and a light weight at the other, to keep it constantly extended, while the heavy weight tends to turn the rollers with their endless cloth round in such a direction as to bring forward the rovings, without putting any strain upon them. Every time that the carriage is pushed home, the larger weight gets wound up; and when the carriage is drawn out, the greater weight turns the roller, and advances the endless apron, so as to deliver the carding at the same rate as the carriage runs out; but when the proper quantity is delivered, a knot in the rope arrives at a fixed stop, which does not permit it to move any further; while at the same instant the roller 5 quits the lever 6, and allows the upper rail G, of the clasp to fall, and pinch the carding fast; the wheel E, being then set in motion, makes the spindles revolve; and the carriage being simultaneously drawn out, extends the slubbings while under the influence of twisting. In winding up the slubbings the operative must take care to push in the carriage, and to turn the wheel round at such rates that the spindles will not take up faster than the carriage moves on its railway, or he would injure the slubbings. The machine requires the attendance of a child, to bring the cardings from the card-engine, to place them upon the sloping feed-cloth, and to join the ends of the fresh ones carefully to the ends of the others newly-drawn under the roller. Slubbings intended for warp-yarn must be more twisted than those for weft; but each must receive a degree of torsion relative to the quality of the wool and of the cloth intended to be made. In general, however, no more twist should be given to the slubbings than is indispensable for enabling them to be drawn out to the requisite slenderness without breaking. This twist forms no part of the twist of the finished yarn, for the slubbing will be twisted in the contrary direction, when spun afterwards in the jenny or mule.

It may here be remarked, that various machines have been constructed of late years for making continuous card-ends, and slubbings, in imitation of the carding and roving of the COTTON SPINNING; to which article therefore the reader may be referred. The wool slubbings are now spun into yarn, in many factories, by means of the mule. Indeed, in France the finest yarn, for the *mousseline-de-laine* fabrics, is beautifully spun upon the self-actor mule of Sharp and Roberts.[1]

Tentering.—When the cloth is returned from the fulling-mill it is stretched upon the tenter frame, and left in the open air till dry.

In the woollen manufacture, as the cloth suffers, by the operation of the fulling-mill, a shrinkage of its breadth to well-nigh one-half, it must at first be woven of nearly double its intended width when finished. Superfine six-quarter broad cloths must therefore be turned out of the loom twelve-quarters wide.

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[1] See this admirable machine fully described and delineated in Dr. Ure's *Cotton Manufacture of Great Britain*, vol. ii.

Burling is the name of a process, in which the dried cloth is examined minutely in every part, freed from knots or uneven threads, and repaired by sewing any little rents, or inserting sound yarns in the place of defective ones.

Teasling.—The object of this operation is to raise up the loose filaments of the woollen yarn into a nap upon one of the surfaces of the cloth, by scratching it either with thistle-heads, called 'teasels,' or with teasling-cards or brushes, made of wire. The natural teasels are the balls which contain the seeds of the plant called *Dipsacus fullonum*; the scales which form the balls, project on all sides and end in sharp elastic points, that turn downwards like hooks. In teasling by hand, a number of these balls are put into a small wooden frame, having crossed handles, eight or ten inches long, and when thus filled, form an implement not unlike a curry-comb, which is used by two men, who seize the teasel-frame by the handles, and scrub the face of the cloth, hung in a vertical position from two horizontal rails, made fast to the ceiling of the workshop. First, they wet the cloth and work three times over, by strokes in the direction of the warp, and next of that of the weft, so as to raise all the loose fibres from the felt, and to prepare it for shearing. In large manufactories, this dressing operation is performed by a machine called a 'gig-mill,' which originally consisted, and in most places still consists of a cylinder bristled all over with the thistle-heads, and made to revolve rapidly while the cloth is drawn over it in a variety of directions. If the thistle be drawn in the line of the warp, the points act more efficaciously upon the weft, being perpendicular to its softer spun yarns. Inventors who have tried to give the points a circular or oblique action between the warp and the weft, proceed apparently upon a false principle, as if the cloth were like a plate of metal, whose substance could be pushed in any direction. Teasling really consists in drawing out one end of the filaments, and leaving the body of them entangled in the cloth; and it should cease and pull them perpendicularly to their length, because in this way it acts upon the ends, which being least implicated, may be most readily disengaged.

When the hooks of the thistles become clogged with flocks of wool, they must be taken out of the frame or cylinder, and cleaned by children with a small comb. Moisture, moreover, softens their points, and impairs their teasling powers; an effect which needs to be counterbalanced, by taking them out, and drying them from time to time. Many contrivances have, therefore, been proposed, in which metallic teasels of an unchangeable nature, mounted in rotatory machines, driven by power, have been substituted for the vegetable, which being required in prodigious quantities, become sometimes excessively scarce and dear in the clothing districts. In 1818, several schemes of that kind were patented in France, of which those of M. Arnold-Merick, and of MM. Taurin frères, of Elbœuf, are described in the 16th volume of 'Brevets d'Invention Expirés.' Mr. Daniell, cloth-manufacturer in Wilts, renewed this invention under another form, by making his rotatory cards with two kinds of metallic wires, of unequal lengths; the one set long, thin, and delicate, representing the points of the thistle; the other, shorter, stiffer, and blunter, being intended to stay the cloth, and to hinder the former from entering too far into it. But none of these processes have succeeded in discarding the natural teasel from the most eminent manufactories.

The French Government purchased in 1807, the patent of Douglas, an English mechanist, who had, in 1802, imported into France, the best system of gig-mills then used in the west of England. A working set of his machines having been placed in the *Conservatoire des Arts*, for public inspection, they were soon introduced into most of the French establishments, so as generally to supersede teasling (*lainage*) by hand. A description of them was published in the third volume of the 'Brevets d'Invention.' The following is an outline of some subsequent improvements:—

1. As it was imagined that the seesaw action of the hand-operative was in some respects more effectual than the uniform rotation of a gig-mill, this was attempted to be imitated by an alternating movement.

2. Others conceived that the seesaw motion was not essential, but that it was advantageous to make the teasels or cards act in a rectilinear direction, as in working by hand; this action was attempted by placing the two ends of the teasel-frame in grooves formed like the letter D, so that the teasel should act on the cloth only when it came into the rectilinear part. Mr. Wells, machine-maker, of Manchester, obtained a patent, in 1832, for this construction,

3. It was supposed that the teasels should not act perpendicularly to the weft, but obliquely or circularly upon the face of the cloth. Mr. Ferrabee, of Gloucester, patented in 1830, a scheme of this kind, in which the teasels are mounted upon two endless chains, which traverse from the middle of the web to the selvage or list, one to the right, and another to the left hand, while the cloth itself passes under them with such a velocity, that the effect, or *resultant*, is a diagonal action, dividing into two equal parts the rectangle formed by the weft and warp yarns. Three patent machines

of Mr. George Oldland—the first in 1830, the second and third in 1832—all proceed upon this principle. In the first, the teasels are mounted upon disks made to turn flat upon the surface of the cloth; in the second, the rotating disks are pressed by cork-screw spiral springs against the cloth, which is supported by an elastic cushion, also pressed against the disks by springs; and in the third machine, the revolving disks have a larger diameter, and they turn, not in a horizontal, but in a vertical plane.

4. Others fancied that it would be beneficial to support the reverse side of the cloth by flat hard surfaces, while acting upon its face with cards or teasels. Mr. Joseph Cliseld Daniell, having stretched the cloth upon smooth level stones, teasels them by hand.

5. Messrs. Charlesworth and Mellor obtained a patent, in 1829, for supporting the back of the cloth with elastic surfaces, while the part was exposed to the teasling action.

6. Elasticity has also been imparted to the teasels, in the three patent inventions of Mr. Sevill, Mr. J. C. Daniell, and Mr. R. Atkinson.

7. It has been thought useful to separate the teasel-frames upon the drum of the gig-mill, by simple rollers, or by rollers heated with steam, in order to obtain the combined effect of calendering and teasling. Mr. J. C. Daniell, Mr. G. Haden, and Mr. J. Rayner, have obtained patents for contrivances of this kind.

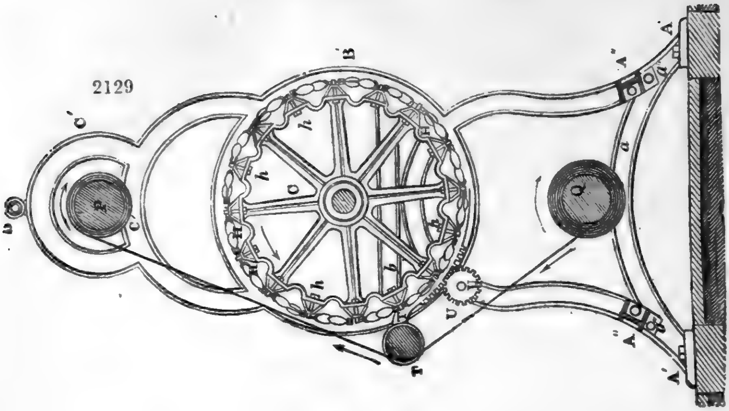
8. Several French schemes have been mounted for making the gig-drum act upon the two sides of the cloth, or even to mount two drums on the same machine,

Mr. Jones, of Leeds, contrived a very excellent method of stretching the cloth, so as to prevent the formation of folds or wrinkles. (See Newton's 'Journal,' vol. viii. 2nd series, page 126). Mr. Collier, of Paris, obtained a patent, in 1830, for a greatly improved gig-mill, upon Douglas's plan, which is now much esteemed by the French clothiers. The following figures (*figs.* 2129, 2130) and description exhibit one of the latest and best teasling machines. It is the invention of M. Dubois & Co., of Louviers, and is now doing excellent work in that celebrated seat of the cloth manufacture.

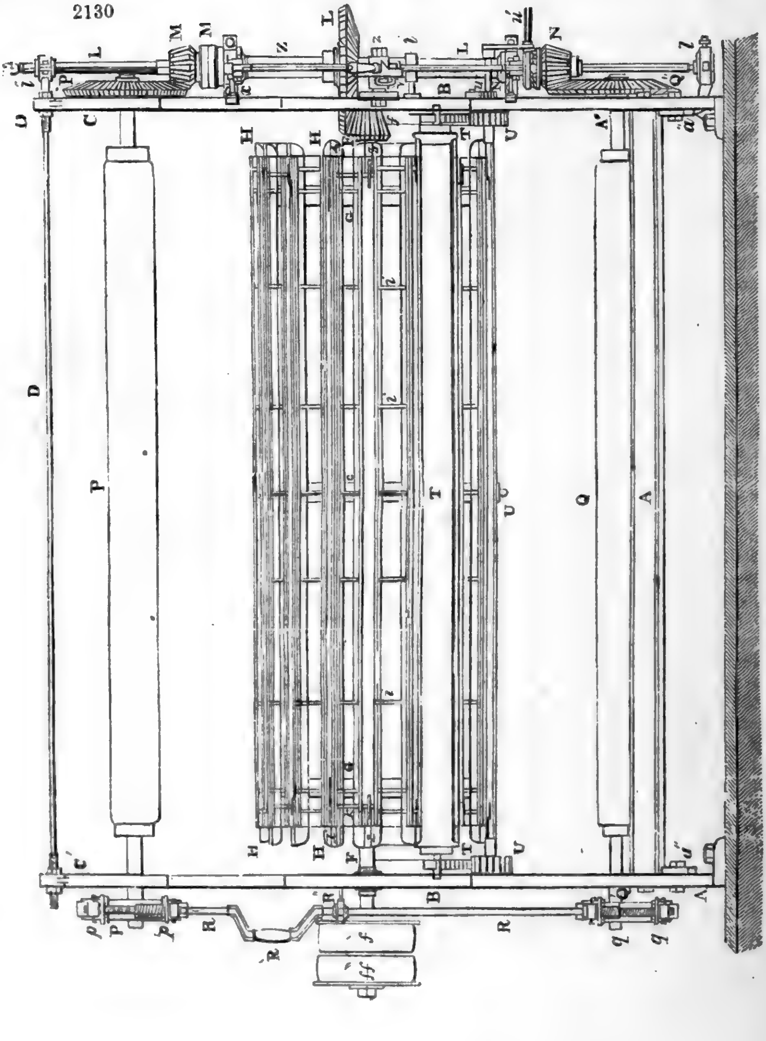
In the fulling mill, the woollen web acquires body and thickness, at the expense of its other dimensions; for being thereby reduced about one-third in length, and one-half in breadth, its surface is diminished to one-third of its size as it comes out of the loom; and it has, of course, increased threefold in thickness. As the filaments drawn forth by teasling, are of very unequal lengths, they must be shorn to make them level, and with different degrees of closeness, according to the quality of the stuff, and the appearance it is desired to have. But, in general, a single operation of each kind is insufficient; whence, after having passed the cloth once through the gig-mill, and once through the shearing-machine (*tondeuse*), it is ready to receive a second teasling, deeper than the first, and then to suffer a second shearing. Thus, by the alternate repetition of these processes, as often as is deemed proper, the cloth finally acquires its wished-for appearance. Both of these operations are very delicate, especially the first; and if they be ill conducted, the cloth is weakened, so as to tear or wear most readily. On the other hand, if they be skilfully executed, the fabric becomes not only more sightly, but it acquires strength and durability, because its face is changed into a species of fur, which protects it from friction and humidity.

Figs. 2129, 2130, represent the gig-mill in section, and in front elevation. A, B, C, D, A′, B′, C′, D′, being the strong frame of iron, cast in one piece, having its feet enlarged a little more to the inside than to the outside and bolted to large blocks in the stone pavement. The two uprights are bound together below by two cross-beams A″, being fastened with screw-bolts at the ears *a″*, *a″*; and at top, by two wrought-iron stretcher-rods D, whose ends are secured by screw-nuts at D, D′. The drum is mounted upon a wrought-iron shaft F, which bears at its right end (*fig.* 2130), exterior to the frame, the usual riggers, or fast-and-loose pulley, *ff″*, *f′*, which give motion to the machine by a band from the main shaft of the mill. On its right end, within the frame, the shaft F, has a bevel-wheel F′, for transmitting movement to the cloth, as will be afterwards explained. Three crown wheels G, of which one is shown in the section, *fig.* 2129, are, as usual, keyed by a wedge to the shaft F. Their contour is a sinuous band, with six semi-cylindrical hollows, separated alternately by as many portions of the periphery. One of these three wheels is placed in the middle of the shaft F, and the other two, towards its extremities. Their size may be judged of, from inspection of *fig.* 2129. After having set them so that all their spokes or radii correspond exactly, the 16 sides H are made fast to the 16 portions of the periphery, which correspond in the three wheels. These sides are made of sheet-iron, curved in a gutter form, *fig.* 2129, but rounded off at the end, *fig.* 2130, and each of them is fixed to the three felloes of the wheels by three bolts *h*. The elastic part of the plate iron allows of their being sufficiently well adjusted, so that their flat portions furthest from the centre may lie pretty truly on a cylindrical surface, whose axis would coincide with that of the shaft F.

2129


B
c'
C'
P
h
H
O
b
U
T
Q
a
A'
A''

2130


M
N
L
Z
l
P
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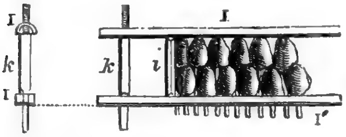
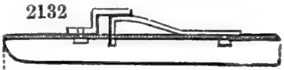
C'
H
G
F
B
T
U
A'
D
P
Q
A
R
f
ff
p
q

Between the 16 sides there are 16 intervals, which correspond to the 16 hollowings of each of the wheels. Into these intervals are adjusted, with proper precautions, 16 frames bearing the teasels which are to act upon the cloth. These are fitted in as follows:—Each has the shape of a rectangle, of a length equal to that of the drum, but their breadth only large enough to contain two thistle-heads set end to end, thus making two rows of parallel teasels throughout the entire length (see the contour in *fig.* 2129). A portion of the frame is represented in *fig.* 2131. The large side I, against which the tops of the teasels rest, is hollowed out in a semi-cylinder, and its opposite side is cleft throughout its whole length, to receive the tails of the teasels, which are seated and compressed in it. There are, moreover, cross-bars *i*, which serve to maintain the sides of the frame I, at an invariable distance, and to form short compartments for keeping the thistles compact. The ends are fortified by stronger bars *k*, *k*, with projecting bolts to fasten the frames between the ribs. The distance of the sides of the frame I, I′, ought to be such, that if a frame be laid upon the drum, in the interval of two ribs, the side I will rest upon the inclined plane of one of the ribs, and the side I′ upon the inclined plane of the other (see *fig.* 2129); while at the same time the bars *k*, of the two ends of the frame rest upon the flat parts of the ribs themselves. This point being secured, it is obvious, that if the ends of the bars *k* be stopped, the frame will be made fast. But they need not be fixed in a permanent manner, because they must be frequently removed and replaced. They are fastened by the clamp, *figs.* 2132, 2133, which is shut at the one end, and furnished at the other with a spring, which can be opened or shut at pleasure. 2 and 4, in *fig.* 2130 (near the right end of the shaft F), shows the place of the clamp, *figs.* 2132, 2133. The bar of the right hand is first set in the clamp, by holding up its other end; the frame is then let down into the left-hand clamp.

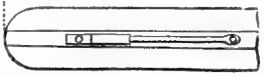
2131



2132



2133



The cloth is wound upon the lower beam Q, *fig.* 2129; thence it passes in contact with a wooden cylinder T, turning upon an axis, and proceeds to the upper beam P, on to which it is wound; by a contrary movement, the cloth returns from the beam P to Q, over the cylinder T; and may thus go from the one to the other as many times as shall be requisite. In these successive circuits it is presented to the action of the teasels, under certain conditions. In order to be properly teasled, it must have an equal tension throughout its whole breadth during its traverse; it must be brought into more or less close contact with the drum, according to the nature of the cloth, and the stage of the operation; sometimes being a tangent to the surface, and sometimes embracing a greater or smaller portion of its contour, it must travel with a determinate speed, dependent upon the velocity of the drum, and calculated so as to produce the best result: the machine itself must make the stuff pass alternately from one winding beam to the other.

In *fig.* 2130, before the front end of the machine, there is a vertical shaft L, as high as the framework, which revolves with great facility, in the bottom step *l*, the middle collet *l*′, and top collet *l*″, in the prolongation of the stretcher D. Upon this upright shaft are mounted—1, a bevel-wheel L′: 2, an upper bevel-pinion M, with its boss M′; 3, a lower bevel-pinion N, with its boss N′. The bevel-wheel L′ is keyed upon the shaft L, and communicates to it the movement of rotation which it receives from the pinion *f*, with which it is in gear; but the pinion *f*, which is mounted upon the shaft F of the drum, participates in the rotation which this shaft receives from the prime mover, by means of the fast rigger-pulley *f*′. The upper pinion M is independent upon the shaft L; that is to say, it may be slidden along it, up and down, without being driven by it; but it may be turned in an indirect manner by means of six curved teeth, projecting from its bottom, and which may be rendered active or not at pleasure; these curved teeth, and their intervals, correspond to similar teeth and intervals upon the top of the boss M′, which is dependent, by feathered indentations, upon the rotation of L, though it can slide freely up and down upon it. When it is raised, therefore, it comes into gear with M. The pinion N, and its boss, have a similar mode of being thrown into and out of gear with each other. The bosses M′ and N′, ought always to be moved simultaneously, in order to throw one of them into gear, and the other out of gear. The shaft L serves to put the cloth in motion, by means of the bevel-wheels P″ and Q″, upon the ends of the beams P and Q, which take into the pinions M and N.

The mechanism destined to stretch the cloth is placed at the other end of the machine, where the shafts of the beams, P, Q, are prolonged beyond the frame, and bear at their extremities P′ and Q′, armed each with a brake. The beam P (*fig.* 2129), turns in an opposite direction to the drum; consequently the cloth is wound upon P, and unwound from Q. If, at the same time as this is going on, the handle R, of the brake-shaft, be turned so as to clasp the brake of the pulley Q′ and release that of the pulley P′, it is obvious that a greater or smaller resistance will be occasioned in the beam Q, and the cloth which pulls it in unwinding, will be able to make it turn only when it has acquired the requisite tension; hence it will be necessary, in order to increase or diminish the tension, to turn the handle R′ a little more or a little less in the direction which clasps the brake of the pulley Q′; and as the brake acts in a very equable manner, a very equable tension will take place all the time that the cloth takes to pass. Besides, should the diminution of the diameter of the beam Q render the tension less efficacious in any considerable degree, the brake would need to be unclamped a very little, to restore the primitive tension.

When the cloth is to be returned from the beam P to the beam Q, Z must be lowered, to put the shaft L out of gear above, and in gear below; then the cloth-beam Q, being driven by that vertical shaft, it will turn in the same direction as the drum, and will wind the cloth round its surface. In order that it may do so, with a suitable tension, the pulley Q′ must be left free, by clasping the brake of the pulley P′ so as to oppose an adequate resistance.

The cloth is brought into more or less close contact with the drum as follows:—There is for this purpose a wooden roller T, against which it presses in passing from the one winding beam to the other, and which may have its position changed relatively to the drum. It is obvious, for example, that in departing from the position represented in *fig.* 2129, where the cloth is nearly a tangent to the drum, if the roller T′ be raised, the cloth will cease to touch it; and if it be lowered, the cloth will, on the contrary, embrace the drum over a greater or less portion of its periphery. For it to produce these effects, the roller is borne at each end, by iron gudgeons, upon the heads of an arched rack T″ (*fig.* 2129), where it is held merely by pins. These racks have the same curvature as the circle of the frame, against which they are adjusted by two bolts; and by means of slits, which these bolts traverse, they may be slidden upwards or downwards, and consequently raise or depress the roller T. But to graduate the movements, and to render them equal in the two racks, there is a shaft U, supported by the uprights of the frame, and which carries, at each end, pinions U′, U″, which work into the two racks T′, T″: this shaft is extended in front of the frame, upon the side of the head of the machine (*fig.* 2130), and there it carries a ratchet-wheel *u*, with a handle *u*′. The workman, therefore, requires merely to lay hold of the handle, and turn it in the direction of the ratchet-wheel, to raise the racks, and the roller T, which they carry; or to lift the click or catch, and turn the handle in the opposite direction, when he wishes to lower the roller, so as to apply the cloth to a larger portion of the drum.

Cloth Cropping.

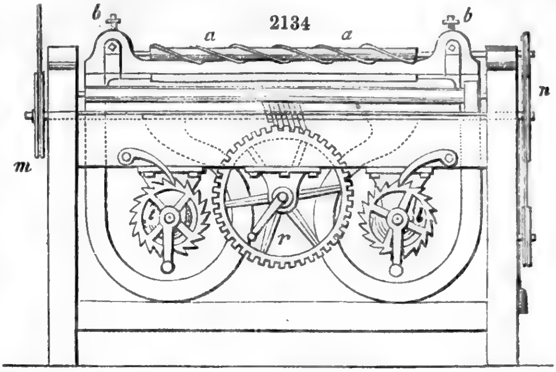
Of machines for cropping or shearing woollen cloths, those of Lewis and Davis have been very generally used.

Fig. 2134 is an end view, and *fig.* 2135 is a side view, of Lewis's machine for shearing cloth from list to list. *Fig.* 2136 is an end view of the carriage, with the rotatory cutter detached from the frame of the machine, and upon a larger scale: *a* is a cylinder of metal, on which is fixed a triangular steel wire; this wire is previously bent round the cylinder in the form of a screw, as represented at *a*, *a*, in *fig.* 2134, and, being hardened, is intended to constitute one edge of the shear or cutter.

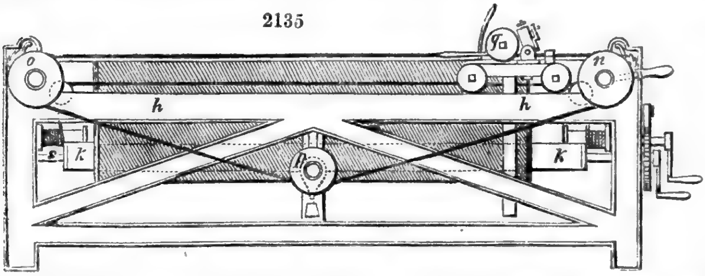
The axis of the cylindrical cutter *a* turns in the frame *b*, which, having proper adjustments, is mounted on pivots *c*, in the standard of the travelling carriage *d*, *d*; and *e* is the fixed or ledger blade, attached to a bar *f*, which constitutes the other edge of the cutter; that is, the stationary blade, against which the edges of the rotatory cutter act; *f* and *g* are flat springs, intended to keep the cloth (shown by dots) up against the cutting edges. The form of these flat springs *f g* is shown at *figs.* 2137 and 2138, as consisting of plates of thin metal cut into narrow slips (*fig.* 2138), or perforated with long holes (*fig.* 2137). Their object is to support the cloth which is intended to pass between them, and operate as a spring bed, bearing the surface of the cloth against the cutters, so that its pile or nap may be cropped off or shorn as the carriage *d* is drawn along the top rails of the standard or frame of the machine *h h*, by means of cords.

The piece of cloth to be shorn is wound upon the beam *k*, and its end is then conducted through the machine, between the flat springs *f* and *g* (as shown in *fig.* 2136), to the other beam *l*, and is then made fast; the sides or lists of the cloth being held and stretched by small hooks, called 'habiting hooks.' The cloth being thus placed in the machine, and drawn tight, is held distended by means of ratchets on the ends of the beams *k* and *l*, and palls. In commencing the operation of shearing, the carriage *a* must be brought back, as in *fig.* 2136, so that the cutters shall be close to the list; the frame of the cutters is raised up on its pivots as it recedes, in order to keep the cloth from injury, but is lowered again previously to being put in action. A band or winch is applied to the rigger or pulley *m*, which, by means of an endless cord passed round the pulley *n*, at the reverse end of the axle of *m*, and round the other pulleys *o* and *p*, and the small pulley *q*, on the axle of the cylindrical cutter, gives the cylindrical cutter a very rapid rotatory motion; at the same time a worm, or endless screw, on the axle of *m* and *n*, taking into the teeth of the large wheel *r*, causes that wheel to revolve, and a small drum *s*, upon its axle, to coil up the cord, by which the carriage *d*, with the cutters *a* and *e*, and the spring bed *f* and *g*, are slowly, but progressively, made to advance, and to carry the cutters over the face of the cloth, from list to list; the rapid rotation of the cutting cylinder *a*, producing the operation of cropping or shearing the pile.

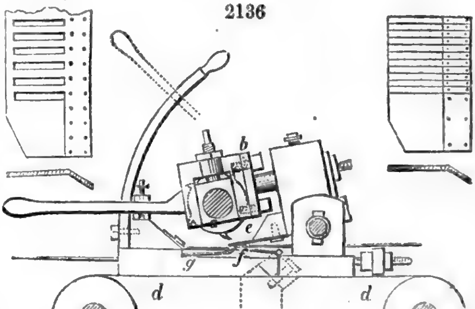
2134



2135



2137 2136 2138

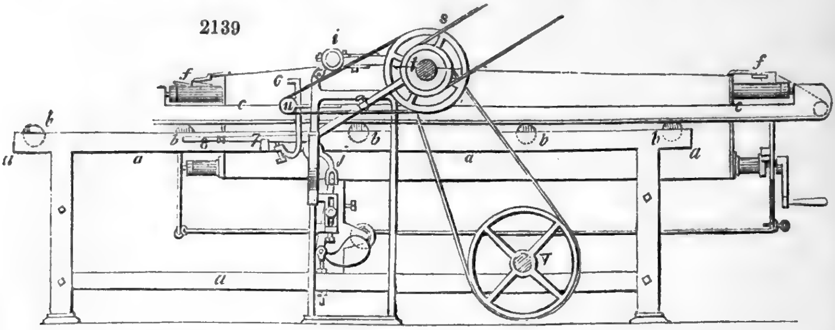


Upon the cutting cylinder, between the spiral blades, it is proposed to place strips of plush, to answer the purpose of brushes, to raise the nap or pile as the cylinder goes around, and thereby assist in bringing the points of the wool up to the cutters.

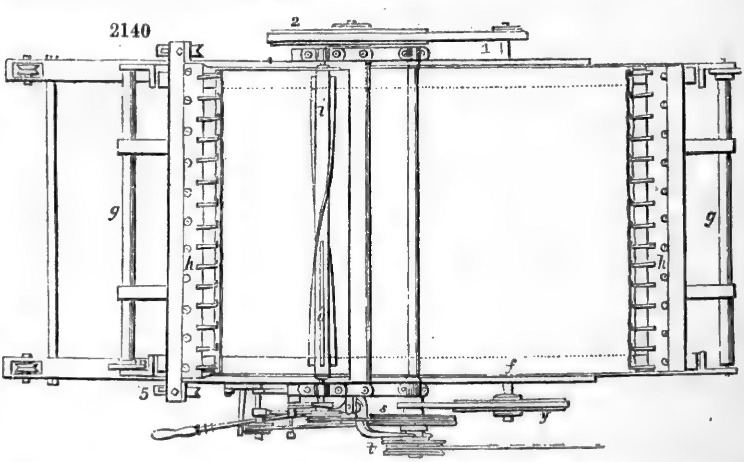
The same contrivance is adapted to a machine for shearing the cloth lengthwise.

Fig. 2139, is a geometrical elevation of one side of Mr. Davis's machine. *Fig.* 2140, a plan or horizontal representation of the same, as seen at top; and *fig.* 2141, a section taken vertically across the machine near the middle, for the purpose of displaying the working parts more perfectly than in the two preceding figures. These three figures represent a complete machine in working condition, the cutters being worked by a rotatory motion, and the cloth so placed in the carriage as to be cut from list to list. *a*, *a*, *a*, is a frame or standard, of wood or iron, firmly bolted together by cross braces at the ends and in the middle. In the upper side-rails of the standard, there is a series of axles carrying anti-friction wheels, *b*, *b*, *b*, upon which the side-rails *c*, *c*, of the carriage or frame that bears the cloth runs, when it is passing under the cutters in the operation of shearing. The side-rails *c*, *c*, are straight bars of iron, formed with edges *v*, on their under sides, which run smoothly in the grooves of the rollers *b*, *b*, *b*. These side-rails are firmly held together by the end stretchers *d*, *d*. The sliding frame has attached to it the two lower rollers *e*, *e*, upon which the cloth intended to be shorn is wound; the two upper lateral rollers *f*, *f*, over which the cloth is conducted and held up; and the two end rollers *g*, *g*, by which the habiting rails *h*, *h*, are drawn tight.

2139



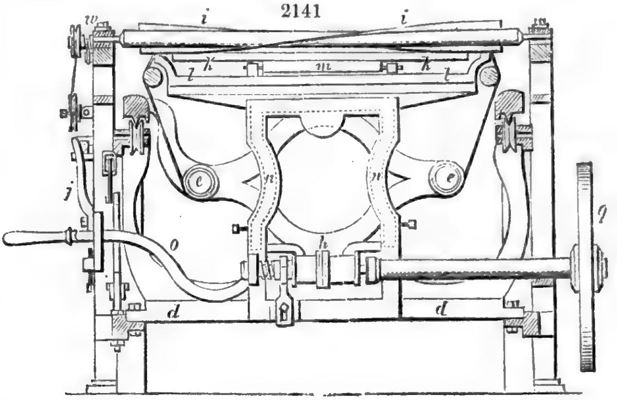
2140



In preparing to shear a piece of cloth, the whole length of the piece is, in the first place, tightly rolled upon one of the lower rollers *e*, which must be something longer than the breadth of the cloth from list to list. The end of the piece is then raised and passed over the top of the lateral rollers *f*, *f*, whence it is carried down to the other roller *e*, and its end or farral is made fast to that roller. The hooks of the habiting rails *h*, *h*, are then put into the lists, and the two lower rollers *e*, *e*, with the two end rollers *g*, *g*, are then turned, for the purpose of drawing up the cloth, and straining it tight, which tension is preserved by ratchet-wheels attached to the ends of the respective rollers, with palls dropping into their teeth. The frame carrying the cloth is now slidden along upon the stop standard rails by hand, so that the list shall be brought nearly up to the cutter *i*, *i*, ready to commence the shearing operation; the bed is then raised, which brings the cloth up against the edges of the shears.

The construction of the bed will be seen by reference to the cross-section *fig.* 2141. It consists of an iron or other metal roller, *k, k*, turned to a truly cylindrical figure, and covered with cloth or leather, to afford a small degree of elasticity. This roller is mounted upon pivots in a frame, *l, l*, and is supported by a smaller roller *m*, similarly mounted, which roller *m*, is intended merely to prevent any bending or depression of the central part of the upper roller or bed *k, k*, so that the cloth may be kept in close contact with the whole length of the cutting blades.

2141

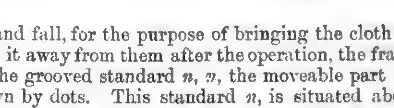


In order to allow the bed *k* to rise and fall, for the purpose of bringing the cloth up to the cutters to be shorn, or lowering it away from them after the operation, the frame *l, l*, is made to slide up and down in the grooved standard *n, n*, the moveable part enclosed within the standard being shown by dots. This standard *n*, is situated about the middle of the machine, crossing it immediately under the cutters, and is made fast to the frame *a*, by bolts and screws. There is a lever, *o*, attached to the lower cross-rail of the standard, which turns upon a fulcrum-pin, the extremity of the shorter arm of which lever acts under the centre of the sliding-frame, so that by the lever *o*, the sliding-frame, with the bed, may be raised or lowered, and when so raised, be held up by a spring-catch *j*.

It being now explained by what means the bed which supports the cloth is constructed, and brought up, so as to keep the cloth in close contact with the cutters, while the operation of shearing is going on; it is necessary, in the next place, to describe the construction of the cutters, and their mode of working; for which purpose, in addition to what is shown in the first three figures, the cutters are also represented detached, and upon a larger scale, in *fig.* 2142.

In this figure is exhibited a portion of the cutters in the same situation as in *fig.* 2136; and alongside of it is a section of the same, taken through it at right angles to the former; *p*, is a metallic bar or rib, somewhat of a wedge form, which is fastened to the top part of the standard *a a*, seen best in *fig.* 2135. To this bar a straight blade of steel *g*, is attached by screws, the edge of which stands forward even with the centre or axis of the cylindrical cutter *i*, and forms the ledger blade, or lower fixed edge of the shears. This blade remains stationary, and is in close contact with the pile or nap of the cloth, when the bed *k*, is raised, in the manner above described.

2142



The cutter or upper blade of the shears, is formed by inserting two or more strips of plate steel, *r, r*, in twisted directions, into grooves in the metallic cylinder *i, i*, the edges of which blades *r*, as the cylinder *i* revolves, traverse along the edge of the fixed or ledger-blade *g*, and by their obliquity produce a cutting action like shears; the edges of the two blades taking hold of the piled or raised nap, as the cloth passes under it, shaves off the superfluous ends of the wool, and leaves the face smooth.

Rotatory motion is given to the cutting cylinder *i*, by means of a band leading from the wheel *s*, which passes round the pulley fixed on the end of the cylinder *i*, the wheel *s* being driven by a band leading from the rotatory part of the steam-engine, or any other first mover, and passed round the rigger *t*, fixed on the axle *s*. Tension is given to this band by a tightening pulley, *u*, mounted on an adjustable sliding-piece *v*, which is secured to the standard by a screw; and this trigger is thrown in and out of gear by a clutch-box and lever, which sets the machine going, or stops it.

In order to give a drawing stroke to the cutter, which will cause the piece of cloth to be shorn off with better effect, the upper cutter has a slight lateral action, produced by the axle of the cutting cylinder being made sufficiently long to allow of its sliding laterally about an inch in its bearings; which sliding is effected by a cam *w*, fixed at one end. This cam is formed by an oblique groove, cut round the axle (see *w*, *fig.* 2142), and a tooth, *x*, fixed to the frame or standard which works in it, as the cylinder revolves. By means of this tooth, the cylinder is made to slide laterally, a distance equal to the obliquity of the groove *w*, which produces the drawing stroke of the upper shear. In order that the rotation of the shearing cylinder may not be obstructed by friction, the tooth *x*, is made of two pieces, set a little apart, so as to afford a small degree of elasticity.

The manner of passing the cloth progressively under the cutters is as follows:—On the axle of the wheel *s*, and immediately behind that wheel, there is a small rigger, from which a band passes to a wheel *y*, mounted in an axle turning in bearings on the lower side-rail of the standard *a*. At the reverse extremity of this axle, there is another small rigger 1, from which a band passes to a wheel 2, fixed on the axle 3, which crosses near the middle of the machine, seen in *fig.* 2141. Upon this axle there is a sliding pulley 4, round which a cord is passed several times, whose extremities are made fast to the ends of the sliding carriage *d*; when, therefore, this pulley is locked to the axle, which is done by a clutch box, the previously-described movements of the machine cause the pulley 4 to revolve, and by means of the rope passed round it, to draw the frame, with the cloth, slowly and progressively along under the cutters.

It remains only to point out the contrivance whereby the machinery throws itself out of gear, and stops its operations, when the edge of the cloth or list arrives at the cutters.

At the end of one of the habiting rails, *h*, there is a stop affixed by a nut and screw 5, which, by the advance of the carriage, is brought up and made to press against a lever 6; when an arm from this lever 6, acting under the catch 7, raises the catch up, and allows the hand-lever 8, which is pressed upon by a strong spring, to throw the clutch-box 10, out of gear with the wheel 8; whereby the revolution of the machine instantly ceases. The lower part of the lever 6, being connected by a joint to the top of the lever *j*, the receding of the lever 6, draws back the lower catch *j*, and allows the sliding frame *l*, *l*, within the bed *k*, to descend. By now turning the lower rollers *e*, *e*, another portion of the cloth is brought up to be shorn; and when it is properly habited and strained, by the means above described, the carriage is slidden back, and the parts being all thrown into gear, the operation goes on as before.

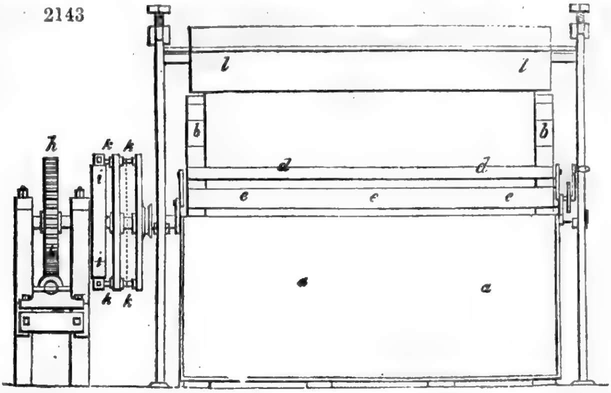
Mr. Hirst's improvements in manufacturing woollen cloths, for which a patent was obtained in February 1830, apply to that part of the process where a permanent lustre is given usually by what is called roll-boiling; that is, stewing the cloth, when tightly wound upon a roller, in a vessel of hot water or steam. As there are many disadvantages attendant upon the operation of roll-boiling, such as injuring the cloths, by overheating them, which weakens the fibre of the wool, and also changes some colours, he substituted, in place of it, a particular mode of acting upon the cloths, by occasional or intermitted immersion in hot water, and also in cold water; which operations may be performed either with or without pressure upon the cloth, as circumstances may require.

The apparatus which he proposed to employ for carrying on his improved process is shown in the accompanying drawings. *Fig.* 2143, is a front view of the apparatus, complete, and in working order; *fig.* 2144, is a section, taken transversely through the middle of the machine, in the direction of *fig.* 2145; and *fig.* 2145 is an end view of the same. *a*, *a*, *a*, is a vessel or tank, made of iron or wood, or any other suitable material; sloping at the back and front, and perpendicular at the ends. This tank must be sufficiently large to admit of half the diameter of the cylinder or drum, *b*, *b*, *b*, being immersed into it, which drum is about four feet in diameter, and about six feet long, or something more than the width of the piece of cloth intended to be operated upon. This cylinder or drum, *b*, *b*, is constructed by combining segments of wood cut radially on their edges, secured by screw-bolts to the rims of the iron wheels, having arms, with an axle passing through the middle.

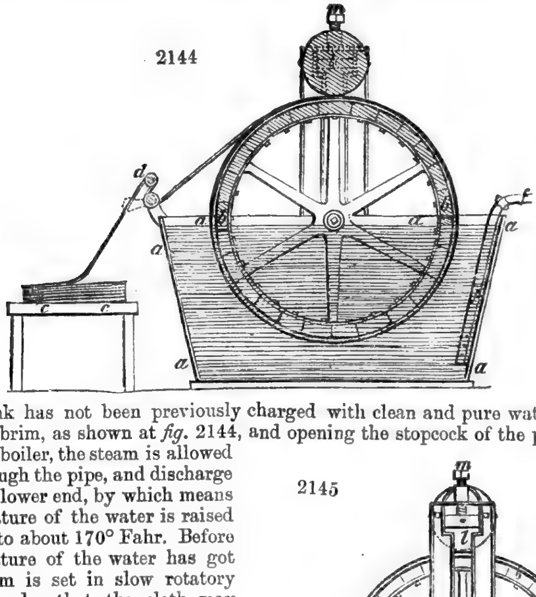
The cylinder or drum being thus formed, rendered smooth on its periphery, and mounted upon its axle in the tank, the piece of cloth is wound upon it as tightly as possible, which is done by placing it in a heap upon a stool, as at *c*, *fig.* 2144, passing its end over and between the tension rollers *d*, *e*, and then securing it to the drum;

the cloth is progressively drawn from the heap, between the tension-rollers, which are confined by a pall and ratchet, on to the periphery of the drum, by causing the drum to revolve upon its axis, until the whole piece of cloth is tightly wound upon the drum; it is then bound round with canvas or other wrappers, to keep it secure.

2143



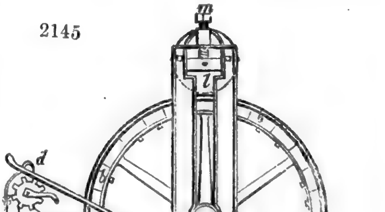
2144



If the tank has not been previously charged with clean and pure water, it is now filled to the brim, as shown at *fig.* 2144, and opening the stopcock of the pipe *f*, which leads from a boiler, the steam is allowed to blow through the pipe, and discharge itself at the lower end, by which means the temperature of the water is raised in the tank to about 170° Fahr. Before the temperature of the water has got up, the drum is set in slow rotatory motion, in order that the cloth may be uniformly heated throughout; the drum making about one rotation per minute. The cloth, by immersion in the hot water, and passing through the cold air, in succession, for the space of about 8 hours, gets a smooth soft face, the texture not being rendered harsh, or otherwise injured, as is frequently the case by roll-boiling.

Uniform rotatory motion to the drum is shown in *fig.* 2143, in which an endless screw or worm is placed horizontally, and driven by a steam-engine or any other first mover employed in the factory. This endless screw takes into the teeth of, and drives, the vertical wheel *h*,

2145



upon the axle of which the coupling-box *i, i,* is fixed, and, consequently, continually revolves with it. At the end of the shaft of the drum, a pair of sliding clutches *k, k,* are mounted, which, when projected forward, as shown by dots in *fig.* 2143, produce the coupling or locking of the drum-shaft to the driving-wheel, by which the drum is put in motion; but on withdrawing the clutches *k, k,* from the coupling-box *i, i,* as in the figure, the drum immediately stands still.

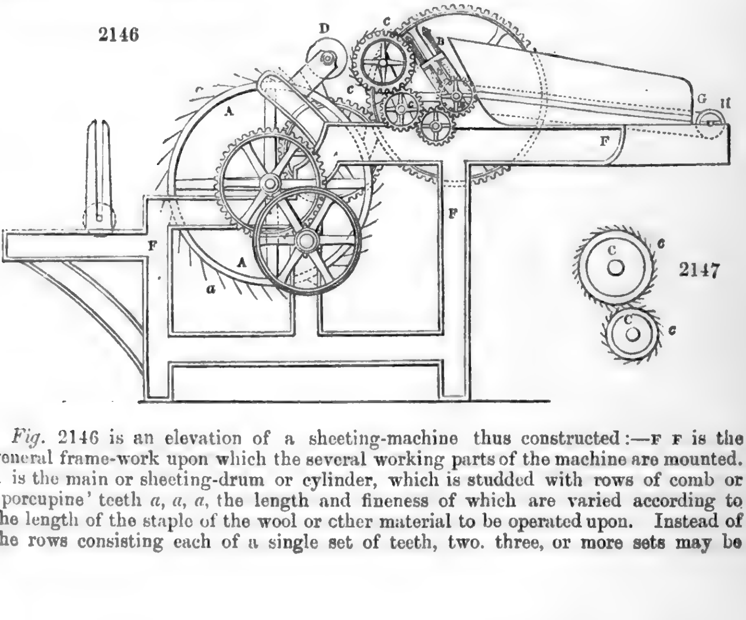
After operating upon the cloth in the way described, by passing it through hot water for the space of time required, the hot water is to be withdrawn by a cock at the bottom, or otherwise, and cold water introduced into the tank in its stead; in which cold water the cloth is to be continued turning, in the manner above described, for the space of 24 hours, which will perfectly fix the lustre that the face of the cloth has acquired by its immersion in the hot water, and leave the pile or nap, to the touch, in a soft silky state.

In the cold-water operation he sometimes employs a heavy pressing-roller *l,* which, being mounted in slots in the frame or standard, revolves with the large drum, rolling over the back of the cloth as it goes round. This roller may be made to act upon the cloth with any required pressure, by depressing the screws *m, m,* or by the employment of weighted levers, if that should be thought necessary.

Pressing is the last finish of cloth to give it a smooth level surface. The piece is folded backwards and forwards in yard-lengths, so as to form a thick package on the board of a screw or hydraulic press. Between every fold sheets of glazed paper are placed to prevent the contiguous surfaces of the cloth from coming into contact; and at the end of every 20 yards, three hot iron plates are inserted between the folds, the plates being laid side by side, so as to occupy the whole surface of the folds. Thin sheets of iron not heated are also inserted above and below the hot plates to moderate the heat. When the packs of cloth are properly folded, and piled in sufficient number in the press, they are subjected to a severe compression, and left under its influence till the plates get cold. The cloth is now taken out and folded again, so that the creases of the former folds may come opposite to the flat faces of the paper, and be removed by a second pressure. In finishing superfine cloths, however, a very slight pressure is given with iron plates but moderately warmed. The satiny lustre and smoothness given by strong compression with much heat is objectionable, as it renders the surface apt to become spotted and disfigured by rain.

Ross's Patent Improvements in Wool-combing Machinery, March 13, 1851.—The first improvements described have relation to the machine for forming the wool into sheets of a nearly uniform thickness, technically known as the 'sheeter,' and consists chiefly in combing with the ordinary sheeting-drum or cylinder-rollers, designated, from their resemblance to porcupine quills, 'porcupine rollers;' these rollers having their teeth or quills set in rows, and the rows of one roller gearing or taking into the spaces between the rows of the other.

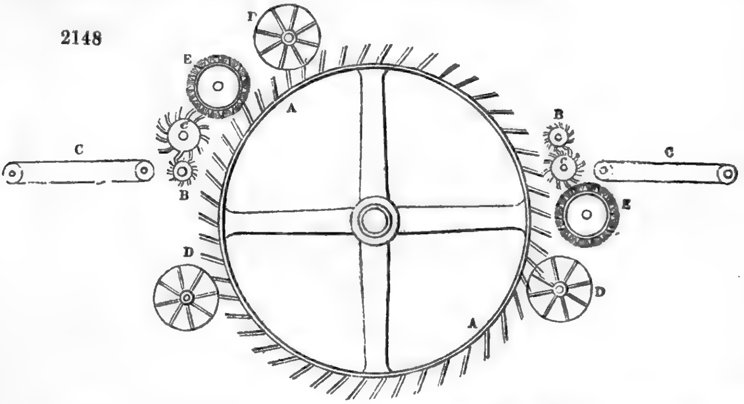
2146



2147

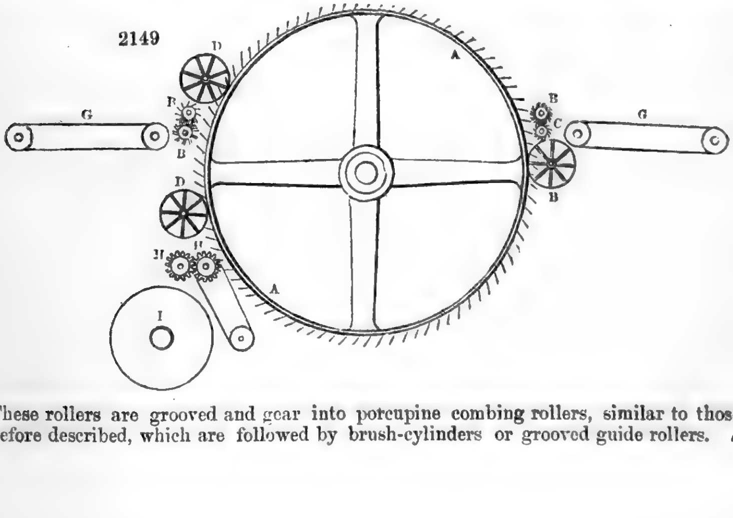
Fig. 2146 is an elevation of a sheeting-machine thus constructed:—F F is the general frame-work upon which the several working parts of the machine are mounted. A is the main or sheeting-drum or cylinder, which is studded with rows of comb or 'porcupine' teeth *a, a, a,* the length and fineness of which are varied according to the length of the staple of the wool or other material to be operated upon. Instead of the rows consisting each of a single set of teeth, two, three, or more sets may be combined together. The number of wires which may be placed on one line should vary with the quality of the wool or other material. In long-staple machines, the number may vary from four to ten or more, and in short-staple machines from five to twenty and more per inch. B, B, are two fluted feed-rollers; C, C, two porcupine combing-rollers, by which the wool is partly combed while passing from the feed-rollers to the surface of the sheeting-drum; an end elevation of the porcupine combing-rollers on an enlarged scale is given at *fig.* 2147. The teeth *c*, *c*, are set in rows, and the rows of one roller take or gear into the spaces between the rows of the other. D is a grooved guide-roller for preventing the wool or other material escaping the combining action. The wool or other material is laid by the attendant evenly upon the upper surface of an endless web G, which works over the under feed-rollers, and a plain roller H, which is mounted in bearings on the front of the machine. The feed-rollers gradually supply the wool thus spread upon the endless web to the two porcupine combing-rollers, where it is partly combed and separated, and being so prepared, it is laid hold of by the teeth of the sheeting-drum, by which it is still further drawn out on account of the greater velocity with which the surface of the sheeting-drum travels. When a sufficient quantity of the wool or other material has been thus collected on the surface of the drum, it is removed by the attendant passing a hooked rod across the surface of the drum, and raising up one end of the sheet, when the whole may be easily stripped off and removed, being then in a fit state for being supplied to the comb-filling machine, next to be described.

2148



A modification of this sheeting-machine is represented in *figs.* 2148, 2149, which differs from it in this, that it is fed from both ends. In this modification a double set of feeding rollers is employed, so that the machine may be fed from both ends.

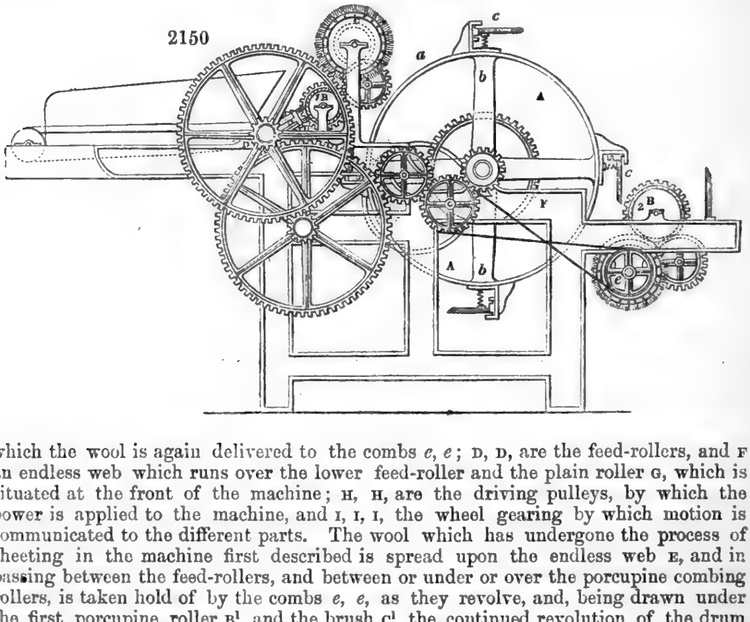
2149



These rollers are grooved and gear into porcupine combing rollers, similar to those before described, which are followed by brush-cylinders or grooved guide rollers. A is the sheeting drum as before; B, B, the fluted feed-rollers; C, C, the porcupine combing-rollers, which gear into the fluted ones; D, D, are the grooved guide-rollers; F, F, are brush-cylinders, which may in the case of long work be dispensed with; G, G, are the endless webs upon which the wool is laid. The framing and gearing by which the several parts are put in motion are omitted in the drawings, for the purpose of clearly exhibiting the more important working parts of the machine. The arrangement of sheeting machines just described, so far as regards the employment of a fluted feed-roller in conjunction with a porcupine combing-roller, and grooved guide-roller, is more especially applicable to sheeting fine short wool, but may also be applied with advantage to wool or other material of a longer staple. In the case of fine short wool, the sheet may be drawn off by means of rollers, in the manner represented in *fig.* 2149. H, H, are the drawing or straightening rollers, and I the receiving roller. During the operation of drawing the wool and winding it on the receiving roller, the sheeting cylinder must have a motion imparted to it in the reverse direction.

The next head of Mr. Ross's specification embraces several improvements in comb-filling machines, which have for their common object the partial combing of the wool while it is in the course of being filled into the combs. We select for exemplification what the patentee regards as the best of these arrangements: *fig.* 2150 is a side elevation of a comb filling machine as thus improved. A, A, is a skeleton drum, which is composed of two rings *a a*, affixed to the arms *b*, *b*, which last are mounted upon the main shaft of the machine, which has its bearings upon the general frame F, F; B^1, B^2 are the porcupine combing rollers, and C^1, C^2 brushes by which the porcupine combing rollers are cleansed from the wool that collects upon them, and by which the wool is again delivered to the combs *e*, *e*; D, D, are the feed-rollers, and F an endless web which runs over the lower feed-roller and the plain roller G, which is situated at the front of the machine; H, H, are the driving pulleys, by which the power is applied to the machine, and I, I, I, the wheel gearing by which motion is communicated to the different parts. The wool which has undergone the process of sheeting in the machine first described is spread upon the endless web E, and in passing between the feed-rollers, and between or under or over the porcupine combing rollers, is taken hold of by the combs *e*, *e*, as they revolve, and, being drawn under the first porcupine roller B^1 and the brush C^1, the continued revolution of the drum and combs causes the wool to be brought into contact with the other porcupine combing roller B^2 and brush C^2. As the combs get filled, the wool is thus continuously being brought under the action of the porcupine combing rollers and brushes; and each new portion of the wool taken up is instantly combed out. For some purposes the combing will be found carried so far by this operation that the wool will require no further preparation previous to being formed into slivers in the machine just described, and which is calculated for filling the combs and combing the wool or other fibrous material, when the staple is some considerable length (say from 4 to 16 inches), there are two porcupine comb rollers with their brushes employed; but the patentee did not confine himself to that number, as in some cases a single porcupine combing roller and brush will be found sufficient for the purpose of facilitating the process of combing and filling the combs; three or more rollers and brush cylinders

2150



may be used with advantage; such as where the staple is short, or where the fibrous material operated upon is very close, and separated with difficulty.

Mr. Ross next describes some improvements in the combing machine of his invention patented in 1841, and now extensively used. The following general description will indicate with sufficient distinctness to those familiar with the machine, the nature of the improvements:—

'First, I give to the saddle combs in the said machine a compound to-and-fro and up-and-down movement, whereby they recede from and advance towards the comb gates, and simultaneously therewith alternately rise and fall, so that each time the comb gates pass the saddle combs, they do so in a different plane, and thus the position of the combs in relation to each other, as well as to the hold they take of the wool or other material, is constantly being changed. Secondly, I employ a fan to lash the wool in the comb gate or flying comb up against the saddle comb, which renders it impossible for the wool to pass by the saddle comb without being acted upon by it. Thirdly, I attach the springs by which the gates are actuated to the lower arms of the combing gates, instead of their being placed parallel to the upright shaft of the machine as formerly, whereby a considerable gain in space and compactness is effected; and fourthly, I use breaks to prevent the sudden jerk which is caused when the wool in the comb gate leaves its hold of the saddle comb or incline plane, and also to counteract the sudden recoil of the springs by which the comb gates are pressed in when these springs are released from the grip or pressure of the incline plane.'

Mr. Ross concludes with a description of an improved method of heating the combs which has for its object 'the economising of fuel, the better heating of the combs, and the prevention of mistakes in removing the combs before they have been a sufficient time exposed to the heat.'

The body of the heating box or stove is divided by a partition into two portions, which communicate together at the back or further end of the stove, so that the flame and heated vapours, after having circulated under and along the sides of the two lower comb chambers, ascend into the upper portion of the stove, where they have to traverse along the sides and over the top of the two upper chambers, ultimately escaping into the chimney through a pipe. The length of the heating box, or the chambers, should be about double the length of the combs. The cold combs are inserted at one end, and on being put into their places push the more heated combs towards the other end of the chambers, from which they are removed. See ALPACA; MOHAIR.

Few of our manufactures have been more stationary than that of woollen goods. Our ancestors appear to have given much attention to the weaving of woollen cloth, and to have produced a fabric of much excellence. All that the moderns have done is to quicken the process of production by the application of steam-power to the machinery employed, and they have introduced, in consequence of this application, a few new and ingenious machines. The sophistication of many woollen fabrics, especially carpets, with the fibre of jute, is destructive of one branch of our woollen manufacture.

EXPORTS.

British Manufactures, 1873.

	lbs.	Value £
Sheep and lambs' wool, British	7,034,735	620,848
Other sorts, including foreign dressed in the United Kingdom, and flocks and ragwool	4,677,983	132,909
Woollen and worsted yarn:		
Woollen (carded)	696,704	101,608
Worsted (combed)	34,047,803	5,291,885

Woollen and Worsted Manufactures.

	lbs.	Value £
Broad cloths, coatings, duffels, &c., plain, all wool	12,960,423	3,093,736
Do. do. wool mixed with other materials	9,933,214	1,503,993
Narrow cloths, coatings, duffels, &c., plain, all wool	6,315,355	945,654
Do. do. wool mixed with other materials	9,424,841	1,056,252
Worsted stuffs, all wool	22,751,815	1,532,783
" wool mixed with other material	260,132,877	12,744,599
Blankets and blanketing	6,202,382	629,677
Flannels	8,244,931	460,187

Woollen and Worsted Manufactures (continued).

			Value £
Carpets, not being rugs	lbs.	9,921,100	1,597,383
Woollen shawls	No.	477,593	179,672
„ rugs, wrappers, &c.	No.	496,498	188,512
„ hosiery		...	288,821
„ small wares, &c.		...	1,128,609
„ yarn, &c.		...	484,548

Foreign and Colonial Produce.

	lbs.	Value £
Wool:—		
Alpaca, vicuña, and llama	136	27
Sheep and lambs'	123,246,063	8,889,898
Other kinds and flocks	347,362	17,902
Woollen yarn	34,777	6,066
„ for weaving	31,554	4,241
„ unenumerated	...	2,136
Woollen manufactures:—		
Cloths and stuffs (pieces)	68,054	223,096
Unenumerated	...	85,753

IMPORTS.

Sheep or Lambs' Wool, 1873.

	lbs.	Value £
From Russia, northern ports	2,721,598	142,492
„ „ southern ports	8,446,965	466,603
„ Denmark	2,110,361	128,633
„ Germany	8,294,628	565,784
„ Holland	646,097	44,161
„ Belgium	1,594,761	92,977
„ France	1,557,165	110,622
„ Portugal	2,454,426	141,258
„ Italy	252,432	14,153
„ Austrian Territories	1,624,591	75,825
„ Turkey	8,234,491	388,347
„ Egypt	4,588,323	211,048
„ Morocco	816,955	48,581
„ United States of America	3,505,387	160,261
„ Peru	2,307,919	130,463
„ Chili	588,265	30,810
„ Uruguay	2,842,742	117,784
„ Argentine Republic	10,733,762	412,158
„ Gibraltar	928,880	44,181
„ British Possessions in South Africa	42,057,187	2,863,250
„ British India: Bombay and Scinde	19,353,258	878,285
„ Australia	186,664,946	11,851,054
„ British North America	299,384	18,663
„ Falkland Islands	246,826	16,327
„ Other countries	625,391	30,156
Total	313,496,742	18,983,876

	lbs.	Value £
Other kinds and wool flocks	712,121	18,318
Woollen yarn for fancy purposes	325,259	59,194
„ weaving	13,169,662	1,496,463
Unenumerated	...	23,457
Woollen manufactures:		
Cloth and stuff (pieces)	345,408	1,428,156
Unenumerated	...	2,418,506

Table showing Quantity of Wool consumed in United Kingdom, 1868–71.

	1868	1869	1870	1871
	lbs.	lbs.	lbs.	lbs.
Production of English wool .	165,549,735	155,591,096	149,516,679	144,985.712
Export of ,, .	9,806,180	11,686,238	10,613,482	10,625,366
Retained for home consumption .	155,743,555	143,904,858	138,903,197	134,360,346
Imports retained for home consumption:—				
Foreign and colonial	130,714,423	164,323,794	145,968,091	196,814,906
Alpaca and mohair	7,505,556	7,970,413	8,083,749	11,249,464
Total	293,963,534	316,199,065	292,955,037	342,424,716
Export of foreign and colonial wool for 12 months ending August 31	94,301,347	110,106,168	121,171,030	117,478,482

From the following Table some idea may be gathered as to the difference in weight of English wool:—

Production of British Wool in 1872.

Counties	No. of sheep and lambs in 1871	Weight per fleece in 1872	Lbs.
		lbs	
Bedford, West and North Ridings, York.	1,508,226	6½	9,803,469
Berkshire, Bucks, Cambridge. . . .	822,109	6¼	5,138,181
Chester, Essex, Monmouth	628,776	4¾	2,986,686
Cornwall, Huntingdon, Kent, Northampton, Leicester	2,339,008	7	16,373,056
Cumberland, Dorset, Norfolk, Salop, Westmoreland	2,453,951	5½	13,496,730
Devon, Gloucester, Nottingham . .	1,509,649	7½	11,322,367
Durham, Rutland	283,734	5¼	1,489,604
Hants, Hereford, Hertford, Lancaster, Oxford, Stafford.	1,931,701	6	11,590,206
Derby, Warwick, Worcester . . .	793,581	5¾	4,563,091
East Riding, York.	482,150	8	3,857,200
Lincoln	1,488,827	8¾	13,027,236
Middlesex, Suffolk.	460,001	5	2,300,005
Northumberland	853,172	6¾	5,758,911
Somerset	639,215	7¼	4,634,309
Surrey, Sussex, Wilts, Isle of Man, Channel Islands.	1,391,517	4¼	5,913,947
Wales	2,706,415	4¾	12,855,471
Scotland	6,882,747	5¼	36,134,422
Ireland	4,228,721	6¼	26,429,506
	31,403,500		187,674,397
Deduction for slaughter between 1871 and 1872	10,650,577	3¼	31,951,731
Net clip of wool, 1872			155,722,666

There is some variation every year in the weight per fleece, according to the season. Probably the clip of 1872 is slightly above the average in weight though not in number.

Imports of Foreign and Colonial Sheep and Lambs' Wool, Alpaca, &c.

(000's omitted).

Years	Total quantities	Australia and New Zealand	Cape and Natal	Spain	Germany	Russia	Other European countries	River Plate	United States	India	Other parts	Alpaca, llama, vicuña, and goats' wool	Years
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1796	3,484	..	..	3,339	14	..	81	..	..	..	50	Alpaca, mohair, &c. is included under other heads previously to 1852	1796
1800	8,608	..	..	6,068	421	..	1,925	..	..	..	197		1800
1801	7,361	..	..	5,395	196	31	1,181	..	..	..	558		1801
1806	6,757	..	..	5,444	715	8	400	..	..	..	191		1806
1811	4,730	..	..	2,581	30	..	2,014	..	..	..	104		1811
1812	6,979	..	..	1,666	..	..	5,245	..	35	..	33		1812
1814	15,479	33	..	6,723	3,581	687	4,413	..	..	..	42		1814
1815	13,634	73	23	6,930	3,243	298	3,013	41	9	..	4		1815
1816	7,516	14	10	2,959	2,833	229	1,211	206	43	..	12		1816
1817	14,051	..	12	6,282	4,924	14	2,628	23	149	1	20		1817
1818	24,718	87	14	8,761	8,674	772	5,838	300	269	2	1		1818
1819	13,736	71	18	4,999	4,163	459	3,111	876	24	..	16		1819
1820	9,776	99	14	3,536	5,221	76	732	69	1	8	20		1820
1821	16,622	175	12	6,969	8,645	67	712	8	..	18	15		1821
1824	22,564	383	25	5,021	15,433	261	1,429	3	1	7	2		1824
1825	43,817	324	28	8,206	28,931	1,992	3,910	331	80	..	15		1825
1826	15,989	1,106	4	1,619	10,599	697	1,307	205	5	128	318		1826
1831	31,652	2,493	48	3,475	23,046	264	2,294	12	16	..	4		1831
1836	64,240	4,997	332	2,818	32,028	5,415	13,250	1,073	633	1,086	2,607		1836
1841	56,180	12,399	1,080	1,088	21,124	4,132	3,562	5,106	59	3,009	4,621		1841
1844	65,070	17,602	2,197	919	22,119	5,402	8,447	2,186	29	2,766	3,410		1844
1845	75,552	24,177	3,513	1,074	18,681	8,709	8,686	2,934	885	3,975	2,966		1845
1846	65,255	21,789	2,958	1,020	16,233	4,766	6,624	314	901	4,571	6,077		1846
1851	83,311	41,810	5,817	383	8,261	5,896	8,323	853	594	4,550	6,820		1851
1856	119,124	52,052	14,305	55	8,640	2,562	11,378	2,568	..	15,386	6,289	5,887	1856
1857	133,005	49,210	14,288	397	5,965	10,308	13,060	3,768	3,782	19,371	7,251	5,614	1857
1858	130,529	51,105	16,598	111	11,009	6,647	10,188	5,235	952	17,334	4,873	6,478	1858
1859	135,786	53,700	14,269	154	12,411	10,978	15,577	3,485	..	14,363	5,845	5,003	1859
1860	151,218	59,166	16,574	1,000	9,954	8,730	18,551	2,875	1,091	20,214	7,345	5,716	1860
1861	150,058	68,506	18,676	631	3,351	12,619	8,145	5,625	1,096	19,161	6,257	6,441	1861
1862	175,991	71,339	18,931	396	8,717	18,187	17,209	6,050	192	17,959	9,857	7,154	1862
1863	180,812	77,173	20,167	256	8,801	13,483	12,893	10,457	678	20,670	9,897	6,837	1863
1864	211,210	99,037	19,881	712	9,628	15,400	17,609	11,303	891	20,425	8,921	7,401	1864
1865	217,609	109,734	29,220	116	7,138	15,050	13,420	10,383	45	17,105	7,202	8,196	1865
1866	243,751	113,773	29,249	123	11,402	16,908	15,160	11,747	1,256	25,680	10,443	8,010	1866
1867	236,351	133,108	36,127	494	4,185	8,065	9,317	11,084	656	15,235	11,953	6,127	1867
1868	259,811	155,745	35,994	663	5,812	8,273	8,059	8,368	827	17,602	9,586	8,882	1868
1869	262,847	158,478	34,308	274	7,309	7,423	10,368	8,027	59	18,797	10,120	7,786	1869

The final 000's are omitted in this table, and must be added to the sums given: thus, the total quantity of wool, &c., imported in 1869 was 262,847,000 lbs.

Imports of Wool in 1874.

	Lbs.	Value
		£
Sheep and lambs'	338,800,481	20,489,055
Alpaca, vicuña, and llama	4,186,381	557,586
Goats' hair or wool	8,013,706	1,046,178
Woollen yarn	13,114,130	1,492,715
" rags	57,361,920	547,279
Woollen Manufacture:		
Of goats' wool, mixed or not with other materials	...	48,404
Of wool other than goats', or of wool mixed with cotton, cloth, and stuffs	Pieces 205,222	1,033,581
Unenumerated	...	2,940,684

Exports of Wool in 1874.

	Yards	Lbs.	Value
			£
Sheep or lambs'	1,047,333	...	918,879
Woollen and worsted yarn	...	34,999,602	5,558,963
Woollen and Worsted Manufactures:			
Woollen cloths, &c.	40,177,001	37,983,903	3,499,409
Worsted stuffs, &c., all wool	22,720,919	8,822,948	1,474,628
,, wool mixed with other materials	238,438,689	55,065,952	10,412,855
Blanketing	7,225,102	8,701,200	850,399
Flannels	8,764,597	3,044,017	484,454
Carpets, not being rugs	9,133,604	15,066,473	1,474,831
Hosiery of wool, &c.	...	...	289,777
Small wares	...	...	1,183,659
Total of woollen and worsted manufactures	...	...	22,794,977

WOOTZ, is the Indian name for Steel. The Indian wootz is prepared in very rude furnaces, in a most primitive manner, from hæmatite and magnetic iron ore; charcoal being the fuel employed. See STEEL.

WORMWOOD (*Artemesia Absinthia*). An intensely bitter herb, used medicinally; and it is said to be sometimes employed as a substitute for hops, in brewing inferior kinds of beer.

WORSTED. Yarns made of long wool drawn out into long filaments by passing it, when oiled, through heated combs, as described under WOOLLEN MANUFACTURE. Numerous machines have been introduced for combing wool, and may now be said to have entirely superseded the old fashion of hand-combing.

X

XANTHINE, the name given by Kuhlmann to the yellow dyeing-matter of madder. See MADDER. The name has also been applied to an animal product.

XANTHORRHŒA. Several species of this genus of *Liliaceæ* are known in Australia as 'grass trees.' They yield 'Botany-Bay resin' and 'Black-boy gum.'

XYLOÏDINE—*Nitramidine.* By acting on starch with fuming nitric acid, a transparent jelly is formed, and on adding water, xyloïdine is precipitated as a white granular substance.

This name has been given to some preparations of collodion which have been prepared by acting on some variety of woody fibre with nitric acid, until it became susceptible of solution in sulphuric ether. Many photographers are of opinion that collodion thus prepared is in many respects superior to that obtained by dissolving gun-cotton in ether. Our own experience does not enable us to pronounce on this, but we have heard some very intelligent operators express a very opposite opinion. Chemically the collodions will be the same, but it is possible that there may be a physical difference, and few, except those who have had much experience in the changes produced by light on chemical compounds, can form any correct idea of the differences in actinic power of producing change in bodies physically different, though chemically the same. Xyloïdine, or rather sawdust treated with a mixture of nitric acid and sulphuric acid, until rendered explosive, has been proposed for use in blasting rocks. Another modified form of the same kind of blasting powder has been made by saturating deal sawdust with nitrate of potash, and then mixing the preparation with some sulphur and yellow prussiate of potash. Neither of these explosive powders has, however, come into use. They are dangerous, as being liable to spontaneous combustion. See COLLODION; GUN-COTTON.

XYLOL. A hydrocarbon found in coal-naphtha and in the oils which separate when crude wood-spirit is mixed with water.

Y

YARN. (*Fil*, Fr.; *Garn*, Ger.) Wool, cotton, or flax, spun into thread.

YEAST. See Beer, and Fermentation.

YEAST, ARTIFICIAL. Mix 2 parts by weight of fine flour of pale barley-malt, with 1 part of wheat-flour; stir 50 lbs. of this mixture gradually into 100 quarts of cold water, with a wooden spatula, till it forms a smooth pap. Put this pap into a copper over a slow fire: stir it well till the temperature rise to fully 155° to 160° Fahr., when a partial formation of sugar will take place, but this sweetening must not be pushed too far; turn out the thinned paste into a flat cooler, and stir it from time to time. As soon as the wort has fallen to 59° Fahr., transfer it to a tub, and add for every 50 quarts of it 1 quart of good fresh beer yeast, which will throw the wort into brisk fermentation in the course of 12 hours. This preparation will be good yeast, fit for bakers' and brewers' uses, and will continue fresh and active for three days. It should be occasionally stirred.

The German yeast imported into this country in large quantities, and employed by our bakers in baking cakes, and other *fancy* bread, is made by putting the *Unterhefe* (see Beer, *Bavarian*) into thick sacks of linen or hempen yarn, letting the liquid part, or beer, drain away; placing the drained sacks between boards, and exposing them to a gradually increasing pressure, till a mass of a thin cheesy consistency is obtained. This cake is broken into small pieces, which are wrapped in separate linen cloths; these parcels being afterwards enclosed in waxed cloth, for exportation. The yeast-cake may also be rammed hard into a pitched cask, which is to be closed air-tight. In this state, if kept cool, it may be preserved active for a considerable time. When this is to be used for beer, the proportion required should be mixed with a quantity of worts at 60° Fahr., and the mixture left for a little to work, and send up a lively froth; when it is quite ready for adding to the cooled worts in the fermenting back.

YEAST, PATENT. Boil 6 ounces of hops in 3 gallons of water 3 hours; strain it off, and let it stand 10 minutes; then add half a peck of ground malt, stir it well up and cover it over; return the hops, and put the same quantity of water to them again, boiling them the same time as before, straining it off to the first mash; stir it up, and let it remain 4 hours, then strain it off, and set it to work at 90°, with 3 pints of patent yeast; let it stand about 20 hours; take the scum off the top, and strain it through a hair-sieve; it will be then fit for use. One pint is sufficient to make a bushel of bread.

Dried Yeast Imported in 1873.

	Cwts.	Value
From Germany	28,060	£79,669
„ Holland	114,445	281,469
„ Belgium	4,711	13,182
„ Other countries . .	10	27
Total . . .	147,226	374,347

Dried yeast *Imported* in 1874: 153,808 cwts.; value 396,067*l.*

YELLOW COPPER ORE. See Copper Pyrites.

YELLOW DYES. (*Teintures jaunes*, Fr.; *Gelbfärben*, Ger.) *Annotto*, *dyer's-broom* (*Genista tinctoria*), *fustic*, *fustet*, *Persian* or *French berries*, *quercitron bark*, *saw-wort*, (*Serratula tinctoria*), *turmeric*, *weld*, and *willow-leaves*, are the principal yellow dyes of the vegetable kingdom; *chromate of lead*, *iron oxide*, *nitric acid* (for silk), *sulphide of antimony*, and *sulphide of arsenic*, are those of the mineral kingdom. Under these articles, as also under Calico-Printing, Dyeing, and Mordants, ample instructions will be found for communicating this colour to textile and other fibrous substances. Alumina and oxide of tin are the most approved bases of the above vegetable dyes. A nankin dye may be given with *bablah*, especially to cotton oiled preparatory to the Turkey-red process. See Madder.

YELLOW, KING'S, is a poisonous yellow pigment. See Arsenic and Orpiment.

YELLOW METAL. See Muntz's Metal.

YEW. *Taxus baccata*, the common yew, yields a durable timber, and was the favourite wood for the old long-bows.

YTTRIA is a rare earth, extracted from the minerals gadolinite and yttrotantalite. It is an oxide of the metal *yttrium.*

Z

ZAFFRE. See Cobalt.

ZEA. Indian corn or maize is obtained from an American grass, the *Zea mays.* It is now largely cultivated in the East Indies and in Northern Africa, and is grown to some extent in the south of Europe. 'Popped corn' is prepared by heating the grains on a hot metal plate, when they open and expose their starchy contents; sweetened and coloured, they form a sweetmeat known as 'cornball.'

ZEDOARY. (*Zédoaire*, Fr.; *Zittwer*, Ger.) The root of a cucurbitaceous plant imported from Ceylon, Malabar, and Cochin-China, employed sometimes medicinally. It occurs in wrinkled pieces, externally ash-coloured, internally brownish-red; possessed of a fragrant odour, and of a pungent, aromatic, bitterish taste.

ZEOLITES. A group of minerals consisting of hydrous silicates of alumina and other bases. They gelatinise with acids, and intumesce when heated, whence their name (*ζέω, zeo,* to boil). They are found in the cavities of amygdaloïdal rocks, and a few also occur in mineral veins. None of them is of any use in the arts.

ZINC (*Atomic weight*, 32·5; *symbol*, Zn) is a metal of a bluish-white colour, of considerable lustre when broken, but easily tarnished by the air; its fracture is hackly, and foliated with small facets, irregularly set. It has little cohesion, and breaks in thin plates before the hammer, unless it has been previously subjected to a process of lamination, at the temperature of from 220° to 300° Fahr., by which it becomes malleable and ductile. On this singular property a patent was taken out by Messrs. Hobson and Sylvester, of Sheffield, many years ago, for manufacturing sheet zinc for covering the roofs of houses, and sheathing ships; but the low price of copper at that time, and its superior tenacity, rendered their patent ineffective. The specific gravity of zinc varies from 6·9 to 7·2, according to the degree of condensation to which it has been subjected. It melts under a red heat, at 773° Fahr. When strongly heated with contact of air, the metal takes fire, and burns with a brilliant bluish-white light, while a few flocculi of a woolly-looking white matter (*nil album*) rise out of the crucible and float in the air. The result of this combustion is a white powder, formerly called 'flowers,' but now oxide of zinc.

The principal ores of zinc are, the sulphide called *blende*, the carbonate called *calamine*, and the silicates of zinc.

1. *Blende* crystallises in rhombic dodecahedrons; its fracture is highly conchoïdal; lustre, adamantine; colours, black, brown, red, yellow, and green; transparent or translucent; spec. grav. 4. It is a simple sulphide of the metal (ZnS); and, therefore, consists in its pure state, of 32·5 of zinc and 16 of sulphur. It dissolves in nitric acid, with disengagement of sulphuretted hydrogen gas. It occurs in beds and veins, accompanied chiefly by galena, iron pyrites, copper pyrites, and heavy spar. There is a radiated variety found at Przibram, remarkable for containing a large proportion of cadmium. Blende is found in great quantities in Derbyshire and Cumberland, as also in Cornwall and many other localities. It is frequently termed 'black jack.'

2. *Calamine* is a mineral occurring usually in concretionary forms and compact masses, yellowish-white when pure, but frequently brown through the presence of iron. It crystallises in rhombohedra, and has a spec. grav. of about 4·4. It is a normal carbonate of zinc ($ZnO.CO^2 = \mathbf{ZnCO^3}$) containing, when pure, about 52 per cent. of zinc. It is an abundant ore in Derbyshire, Cumberland, Belgium, Sardinia, Silesia, &c. The carbonate is termed by some writers Smithsonite, a name applied by others to the hydrous silicate. See Calamine.

3. *Smithsonite* or *Electric calamine* is an ore occurring in compact masses, and in mammillated, botryoïdal, and fibrous forms. It is found in Carinthia, Hungary, Belgium, New Jersey, &c. It is a hydrous silicate, containing $2ZnO.SiO^2 + HO$ ($\mathbf{Zn^2SiO^4 + H^2O}$). Many writers term this ore calamine.

4. *Willemite.* An anhydrous silicate of zinc, containing $2ZnO.SiO^2$ ($\mathbf{Zn^2SiO^4}$). It is found at Vieille Montagne, near Aix-la-Chapelle, and at Franklin and Stirling, in New Jersey.

5. *Zincite*, *Spartalite*, or *Red zinc ore* occurs at Mine Hill and Sterling Hill in New Jersey, where it is associated with franklinite. It is an oxide of zinc (ZnO) containing a little oxide of manganese. An artificial oxide of zinc is sometimes found crystallised among blast-furnace products.

The zinc ores of England, like those of France, Belgium, and Silesia, occur in two geological positions. The first is in the carboniferous or mountain limestone. The blende and the calamine most usually accompany the veins of galena which traverse that limestone; though there are many lead mines that yield no calamine; and, on the other hand, there are veins of calamine alone, as at Matlock.

In almost every part of England where metalliferous limestone appears, there are explorations for lead and zinc ores. The neighbourhood of Alston-moor, in Cumberland, of Castleton and Matlock, in Derbyshire, and the small metalliferous belt of Flintshire, are peculiarly marked for their mineral riches. On the north side of the last county, calamine is worked in a rich mine of galena at Holywell, where it presents the singular appearance of occurring only in the ramifications that the lead-vein makes from east to west, and never in those from north to south; while the blende, abundantly present in this mine, is found indifferently in all directions.

The second locality of calamine is in the magnesian limestone formation. The calamine is disseminated through it in small contemporaneous veins, which, running in all directions, form the appearance of a network. These veins have commonly a thickness of only a few inches; but in certain cases they extend to 4 feet, in consequence of the union of several small ones into a single mass. There were formerly explorations for calamine in the magnesian limestone, situated chiefly on the flanks of the Mendip Hills, a chain which extends in the north-west and south-east direction, from the Canal of Bristol to Frome. Calamine was chiefly worked in the parishes of Phipham and Roborough, as also near Rickford and Broadfield-Doron, by means of a great number of small shafts. The miners paid for the privilege of working a tax of 1*l.* sterling per annum, to the Lords of the Treasury; and they sold the ores, mixed with a considerable quantity of carbonate of lime, at Phipham, after washing it slightly in a sieve. Very little is at present worked in this district. Calamine is now largely imported into this country from Spain and the United States of America.

METALLURGY OF ZINC.

Roasting of Ores.—Blende, or sulphide of zinc is, previous to its treatment for metal, carefully roasted in a reverberatory furnace, over the bottom of which it is spread in a layer of about 4 inches in thickness. A strong heat is necessary for this purpose, and during the operation the charge is frequently stirred with a strong iron rake, with a view of exposing fresh surfaces to the gases of the furnace. The apparatus most commonly employed in this country for roasting sulphide of zinc consists of a reverberatory furnace about 36 feet in length and 9 feet in width, provided with a fireplace of the usual construction. The sole or hearth of this apparatus is divided into three distinct beds, of which that nearest the fire-bridge is 4 inches lower than that which is next it, which is again 4 inches lower than that nearest the chimney. In addition to the heat derived from the fireplace, the gases escaping from the reducing furnaces are usually introduced immediately before the bridge, and a considerable economy of fuel is thereby effected.

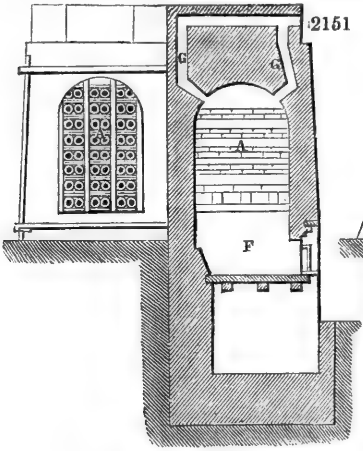
When the furnace has been sufficiently heated, a charge of 12 cwts. of raw blende is introduced into the division nearest the chimney, and equally spread over the bottom, care being taken to stir it from time to time by means of an iron rake, as before described. After the expiration of about eight hours this charge is worked on to the floor of the compartment forming the middle of the furnace, and a new charge is introduced into the division next the chimney. About eight hours after this charging the ore on the middle bed is worked on to the first, whilst that on the hearth next the chimney is equally spread on the middle one and a new charge introduced into the division next the stack. After the expiration of another period of eight hours the charge on the first hearth is drawn, the ore on the middle and third hearths moved forward, and a fourth charge introduced as before. In this way the operation is continuous, and each furnace will effect the calcination of about 36 cwts. of ordinary blende in the course of 24 hours.

Calamine is usually prepared for smelting by calcination in a furnace resembling an ordinary lime-kiln, the heat being often supplied by means of four fireplaces arranged externally, and so placed that the heated gases may be drawn into it, and regularly distributed through the interstices existing between the masses of ore. Calamine subjected to this treatment commonly loses about one-third of its weight, and is at the same time rendered so friable as easily to admit of being reduced to fine powder by an ordinary edge-mill.

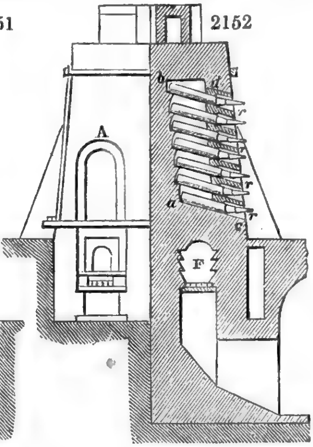
Belgian Process.—When this method of treating zinc ore is employed, the furnace represented in *fig.* 2151 is commonly used.

Fig. 2151 represents, on the left hand, a front elevation of the furnace, and on the right a sectional elevation through the ash-pit and fireplace. F is the fireplace, whilst A is the cavity into which are introduced the retorts destined for the distillation of the metal. The products of combustion escape by the openings G into a flue, by which they are conducted into the calciner for the purpose of economising the waste heat. These furnaces are either arranged in couples, back to back, or in groups of four, for the purpose of rendering the structure more solid, and economising heat.

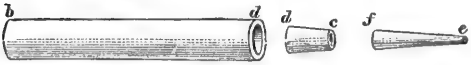
In the arched chamber A are placed 48 cylindrical retorts, 3 feet 6 inches in length from *b* to *d*, and 7 inches internal diameter. These are made of refractory fire clay, well baked and supported behind by ledges of masonry *a*, *b*, *fig.* 2152, whilst in front, at *c d*, they rest on fire-clay saddles let into an iron framing. Short conical fire-clay pipes, 10 inches in length from *d* to *c*, are fixed in the mouths of these retorts by means of moistened clay, and project for a short distance beyond the mouth of the furnace. To these are adapted thin wrought-iron cones 18 inches in length from *e* to *f*, tapering off to the smaller extremity to an orifice of about three quarters of an inch in diameter. The inclined position of the retorts, the method of adjusting the pipes, and the general arrangement of the apparatus are shown in *fig.* 2152, in which *r*, *r*, *r*, *r*, represent the nozzles of thin wrought iron. When a new furnace is first lighted the retorts are introduced without being previously baked, but care must be taken that they be perfectly dry and seasoned, and for this reason it is necessary to keep a large stock constantly on hand, in a storehouse artificially heated by means of some of the flues of the establishment. The heat is gradually increased during three or four days, at the end of which period charges of ore are introduced, the clay cones are luted in their places, and the furnace is brought into full working order. The charge of a furnace consists of 1,680 lbs. of roasted blende, or calcined calamine, and 840 lbs. of coal-dust. The ore and coal-dust, after being finely divided and intimately mixed, is slightly damped and subsequently introduced into the retorts by means of a semi-cylindrical scoop, by the aid of which an experienced workman will effect the charging without spilling the smallest quantity of the mixture.



2151



2152



In this country the retorts in the lower tier are usually not charged, as they are extremely liable to be broken, and are therefore only employed to moderate the heat of the furnace. On the Continent, however, the fireplace is frequently covered by a hollow arch, and in that case every retort requires a charge of ore.

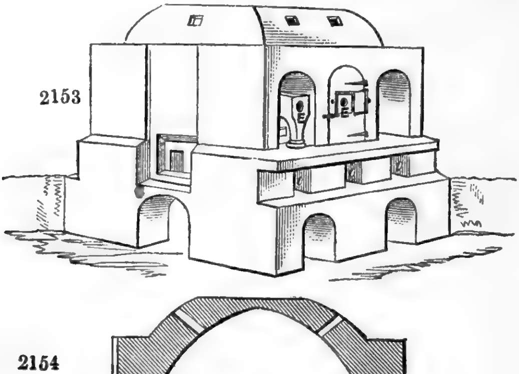
The mixture introduced into the retorts varies, to a certain extent, with their position in the furnace, for in spite of every precaution to prevent inequality of temperature, it is found impossible to heat the whole of them alike, and those next the fire, therefore, from being the most strongly heated, are liable to work off first. As soon as the retorts have been charged the clay cones are luted into their places, and carbonic oxide gas, which burns with a blue flame at the mouth of the cones, quickly makes its appearance. The quantity of this gas gradually diminishes, and as soon as the flame assumes a greenish-white hue, and white fumes are observed to be evolved, the sheet-iron cones are put on, and the furnace at once enters into steady action. From time to time, as the iron cones become choked with oxide, they are taken off and gently tapped against some hard substance, so as to remove it, and then replaced. The oxide thus collected is added to the mixture prepared for the next charge. After the expiration of about six hours from the time of charging the wrought-iron tubes are successively removed, and the metallic zinc scraped from the clay-pipes into an iron ladle. This, when full, is skimmed, and the oxide added to that obtained from the nozzles, whilst the pure metal is cast into ingots, weighing about 28 lbs. each. At the expiration of twelve hours from the time of charging, the zinc is again tapped, and the residue remaining in the retorts withdrawn. The retorts are immediately recharged, and the operation of reduction is conducted as above described.

The residues obtained from the retorts, after the first working, are passed through a crushing-mill, mixed with a further quantity of small coal, and again treated for the metal they contain. The earthen adapters or cones, when unfit for further service, are crushed and treated as zinc ores.

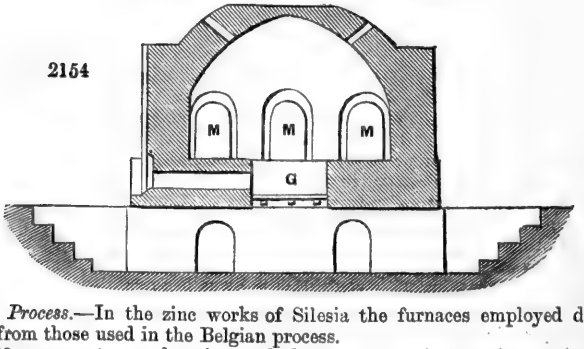
In order to work these furnaces with economy, it is of the greatest importance that they should be constantly supplied with a full number of retorts, since the amount of fuel consumed, and the general expenses incurred for each furnace, will be the same if the apparatus has its full complements of retorts, or if one half of them are broken and consequently disabled.

It is therefore necessary, in all zinc-smelting establishments, to keep a large stock of well-seasoned retorts, which, before being introduced into the furnace, to make good any deficiency caused by breakage, are heated to full redness in a kiln provided for that purpose. The Belgian process of zinc smelting is that which is at present most employed in this country. The principal localities in which zinc ores are treated are Swansea, Wigan, Llanelly, and Wrexham.

2153



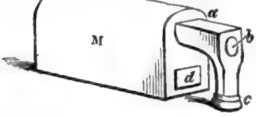
2154



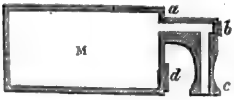
Silesian Process.—In the zinc works of Silesia the furnaces employed differ considerably from those used in the Belgian process.

Fig. 2153, represents an elevation, and *fig.* 2154, a vertical section of the Silesian furnace. The distillation is effected in a sort of muffle of baked clay, M, *figs.* 2155 and 2156; these are each about 3 feet 3 inches in length, and 20 inches in height. The front of this muffle is pierced with two apertures. The lower opening, *d*, serves to remove the residues remaining in the retorts after each operation, and is closed during the process of distillation by a small door of baked clay, firmly luted in its place. In the upper opening is introduced a hollow clay arm, bent at right angles, *a*, *b*, *c*, and which remains open at *c*. An opening at *b*, permits of charging the retort by means of a proper scoop, and this, during the operation, is closed by a luted clay-plug. From six to ten of these muffles or retorts are arranged in rows, on either side of a furnace provided with suitable apertures for their introduction. They are securely luted in their places, and the openings closed by sheet-

2155



2156

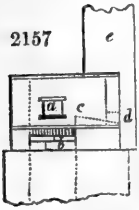


iron doors, by which the too rapid cooling of the pipe *a*, *b*, *c*, is prevented. The fuel employed is coal, which is burnt on the grate G, situated in the centre of the furnace. The retorts are charged with a mixture of calamine and small coal, or more frequently coke-dust, since, when coal is employed, the products of distillation are found to be liable to choke the pipe *a*, *b*, *c*.

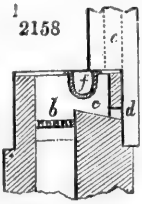
The zinc escapes by the opening *c*, of the adapter, and is received into the cavities *o*, of the furnace.

The furnace shown in *figs.* 2157, 2158, 2159, is for remelting the metallic zinc. *Fig.* 2157, is a front view; *fig.* 2158, is a transverse section; *fig.* 2159, a view from above: *a*, is the fire-door; *b*, the grate; *c*, the fire-bridge; *d*, the flue; *e*, the chimney; *f*, *f*, *f*, cast-iron melting-pots, which contain each about 10 cwts. of metal. The heat is moderated by the successive addition of pieces of cold zinc. The inside of the pots is sometimes coated with loam, to prevent the iron being attacked by the zinc.

2157



2158



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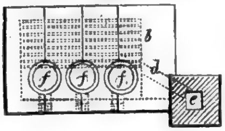
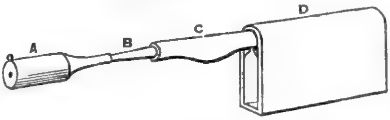


In some establishments, and particularly those at Stolberg in Prussia, the retorts have the form represented by D, *fig.* 2160, C is an adapter also of fire-clay; B a cone of wrought iron, and A a small vessel of the same material for the collection of the oxide, and furnished in the bottom with an aperture for the escape of the gases generated.

2160



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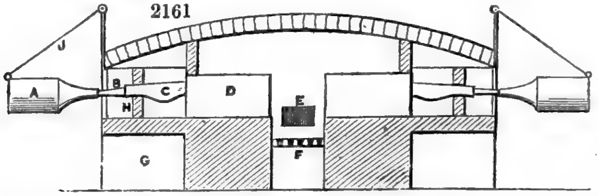
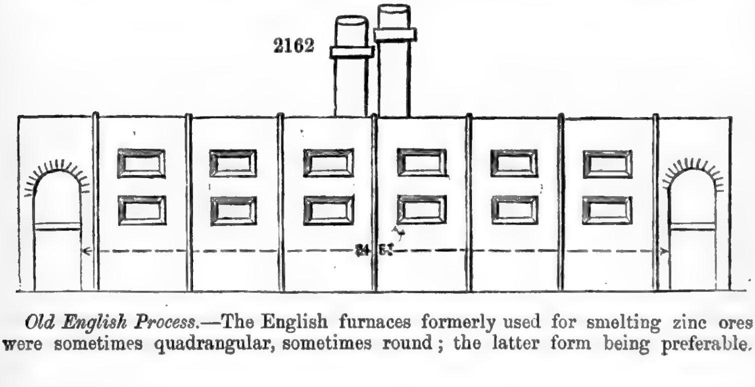


These are arranged on either side of a grate as represented, *fig.* 2161; an internal opening serving for two retorts, and of which there are usually twelve in each furnace. E is the fire-door; F grate; G chamber in masonry of furnace; H diaphragm of fire-brick supporting adapter, in the depressed part of which the metallic zinc is collected and subsequently removed by a scraper, as in the case of the cone of the Belgian retort. The wrought-iron vessel A, is supported by a chain or wire J.

Fig. 2162 represents a longitudinal elevation of the roasting furnace employed.

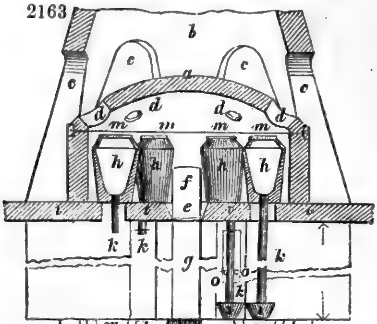
2162



Old English Process.—The English furnaces formerly used for smelting zinc ores were sometimes quadrangular, sometimes round; the latter form being preferable.

They were mounted with from 6 to 8 crucibles or pots (*figs.* 2163, 2164), arched over with a cupola *a*, placed under a conical chimney *b*, which served to give a strong draught, and to carry off the smoke. In this cone there were as many doors, *c, c, c,* as there were pots in the furnace; and an equal number of vents *d, d, d,* in the cupola, through which the smoke might escape, and the pots be set. In the surrounding wall there were holes for taking out the pots when they became unserviceable; after the pots were set, these holes were bricked up. The pots were heated to ignition in a reverberatory furnace before being set, and were put in by means of iron tongs supported upon two wheels, as is the case with glass-house pots. In *figs.* 2163, 2164, *e,* is the grate; *f,* the door for fuel; *g,* the ash-pit. The pots, *h, h, h,* have a hole in the centre of their bottom, which is closed with a wooden plug, when they are set charged with calamine, mixed with coal; which coal prevents the mixture from falling through the orifice, when the heat rises and consumes the plug. The sole of the hearth *i, i,* upon which the crucibles stand, is perforated under each of them, so that they can be reached from below; to the bottom orifice of the pots, when the distillation begins, a long sheet-iron pipe, *k,* is joined, which dips at its end into a vessel, *l,* for receiving in drops the condensed vapours of the zinc. The pot is charged from above, through an orifice in the lid, which is left open after the firing until the bluish colour of the flames indicates the volatilisation of the metal, immediately whereupon the whole is covered with a fire-tile, *m.* The iron tubes are liable to become obstructed during the distillation, and must therefore be occasionally cleared by means of an iron bar. When the operation is terminated the pipes must be removed, and the carbonaceous and other residual matters extracted from the pots. In this figure, 1, 2, is the level of the upper floor; 3, 4, level of the lower ceiling of the lower floor. *Fig.* 2164 is a ground plan on the level of 1, 2; only one half being here shown.—J. A. P.

2163



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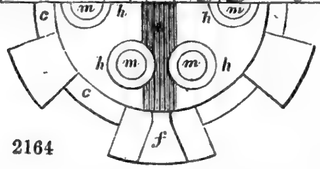

The general consumption of Spelter throughout the world is about 67,000 tons per annum; of which about 44,000 tons are made to take the shape of rolled sheets, and these are estimated to be applied as follows, each quantity being somewhat below the truth:—

	Tons.
Roofing and architectural purposes	23,000
Ship-sheathing	3,500
Lining packing-cases	2,500
Domestic utensils	12,000
Ornaments	1,500
Miscellaneous	1,500
	44,000

Five-and-twenty years ago the quantity used for roofing did not exceed 5,000 tons; none was employed for ship-sheathing or lining packing-cases; and stamped ornaments in zinc date only from 1852.

From the low temperature at which zinc fuses, and from the sharpness of impressions possessed by castings in this metal, it is much employed on the Continent for the production of statues and statuettes. The uses of this metal in the preparation of alloys has already been noticed under the head of ALLOYS. It is also employed like tin for coating iron, producing what is known as 'galvanised iron.' (See GALVANISED IRON.) The *disinfectant liquor* of Sir W. Burnett is chloride of zinc, and the oxide of this metal is much employed as a pigment in place of white lead. (See BURNETT'S FLUID, and ZINC WHITE.)

Imports of Zinc in the Year 1873 *and three previous Years* (*as per Board of Trade Returns*).

Years	Crude Zinc		Zinc manufactures	
	Quantities	Value	Quantities	Value
	Tons	£	Tons	£
1870	19,921	366,461	9,360	220,394
1871	20,968	431,309	8,792	207,855
1872	14,874	302,329	12,417	340,827
1873	20,038	478,628	12,470	367,935

Zinc Imported in 1874.

	Quantities	Value
Crude, in cakes . . .	22,216 tons	£492,874
Manufactures . . .	252,607 cwts.	372,176

British Zinc or Spelter Exported in the Year 1873 *and four previous Years* (*as per Board of Trade Returns*).

Years	Quantities	Value
	Tons	£
1869	10,145	207,840
1870	7,345	141,281
1871	6,452	115,281
1872	5,047	101,812
1873	3,439	85,739

ZINCING OF IRON. Iron may be conveniently coated, in the humid way, by a solution of sulphate of zinc, or one of the double salts of chloride of zinc and sal-ammoniac, as now used in soldering and welding. To secure success, the zinc solution should be weak, and only a weak galvanic current should be used, otherwise the zinc precipitated will again separate from the iron in scales. With proper precautions, the deposit may be made as thick as strong paper. The article must be well cleansed before undergoing the operation. See GALVANISED IRON.

ZINC PRINTING. If this art be not calculated to supersede wood engraving, it can be applied with great advantage for certain purposes in the etching style, for maps, plans, drawings of machines, &c. A zinc plate is covered with an etching ground, the drawing etched in the usual manner with the needle, and bitten in. The etching ground is now removed, the deep lines cleaned with acid, and then the whole plate, in a warm state, covered with an easily fusible metal, with which, of course, the lines of the drawing are filled up. When the metal thus laid on is cold and firm, the whole plate is planed until the zinc appears again, and only the lines of the drawing remain filled with the fusible metal, which is easily distinguished by its white colour from the gray of the zinc. The whole plate is now etched several times; the former lines of the drawing, filled with easily fusible negative metal, are not affected by the acid, while the pure zinc is eaten away. In this manner a drawing for printing in the copper-plate press can be converted into one in relief for use in ordinary printing press.

ZINC WHITE. Under this name oxide of zinc is now largely used as a substitute for white lead. For this purpose it is prepared by heating metallic zinc in earthenware retorts, and bringing the zinc-vapour into contact with a current of air, whereby it becomes oxidised. Instead of using metallic zinc, the reduction of the ore and oxidation of the metal may be performed at one operation. Thus, at the New Jersey Works and the Lehigh Zinc Works a mixture of ore and charcoal is treated in muffle-furnaces, and the oxide obtained is blown into chambers, in which it is collected in large muslin bags. In some Continental works the metallic zinc is exposed to the action of superheated steam, when oxide of zinc is formed, whilst hydrogen is liberated, the gas being applied in some cases to illuminating purposes.

ZIRCON. See HYACINTH and GEMS.

ZIRCONIA is a rare earth, extracted from the mineral zircon, which is a silicate of zirconia. Zirconia itself is an oxide of zirconium. It has lately been proposed to employ zirconia, instead of lime or magnesia, in the preparation of cylinders for the oxyhydrogen light.

ZIRCONIUM may be prepared in an amorphous form by passing the vapour of chloride of zirconium over heated sodium, or by heating the double fluoride of zirconium and potassium with an alkaline metal, and treating the product with dilute nitric acid. Thus prepared, it appears as a dull brown powder, combustible in the air at a temperature below redness.

M. Troost wished to determine whether zirconium, already found in this amorphous state by Berzelius, was a metal similar to magnesium, or aluminium, or a metalloïd not unlike carbon, boron, or silicon. He obtained crystallised zirconium by heating the fluoride of zirconium and potassium with excess of aluminium, and removing the aluminium by solution from the insoluble residue. The zirconium thus obtained appears in hard brittle crystalline laminæ, of specific gravity 4·15.

Zirconium in its chemical properties approaches near to silicium, and perhaps even nearer to titanium. Crystalline zirconium withstands the action of oxygen at a red heat, becomes slightly oxidised at a white heat, and burns only when subjected to the oxyhydrogen-flame. It burns in chlorine, however, at a dull heat. Cold acids have no action upon it, and warm acids affect it but slightly. Its true solvent is hydrofluoric acid. Like silicium, zirconium presents three different physical conditions, viz. the amorphous, graphitoïd, and crystallised. Zirconium forms only one oxide, known as *zirconia.*

ZIZANIA. It has recently been suggested to employ Canada Grass (*Zizania aquatica*) as a paper-making material. This plant grows abundantly on the shores of Lakes Erie, Ontario, and St. Clare, and is known to the Indians as *Tuscarora.* The fibre is said to be easily bleached and comparatively free from silica, while it yields a paper of good colour and texture, well adapted to the printer's use. It is asserted that a supply of 100,000 tons per annum may be readily obtained from Canada.

ZIZYPHUS. Several species of this genus of the Buckthorn order (*Rhamnaceæ*) yield edible fruits. *Z. Jujuba*, and some others, furnish the fruit known as *jujube.*

ZORGITE. A selenide of lead and copper, from Zorge and Tilkerode in the Hartz.

ZOSTERA. The Grass-wrack (*Zostera marina*) is a marine plant common on the coast of Britain. It is collected and dried for use as a substitute for hay in packing.

THE END.

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